BS EN 61095:2009

BSI British Standards

Electromechanical contactors for household and similar purposes

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British Standards

National foreword

This British Standard is the UK implementation of EN 61095:2009. It is identical to IEC 61095:2009. It supersedes BS EN 61095:1993 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee PEL/17, Switchgear, controlgear, and HV-LV co-ordination, to Subcommittee PEL/17/2, Low voltage switchgear and controlgear.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Compliance with a British Standard cannot confer immunity from legal obligations.

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EUROPEAN STANDARD

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Supersedes EN 61095:1993 + A1:2000

English version

Electromechanical contactors for household and similar purposes (IEC 61095:2009)

Contacteurs électromécaniques pour usages domestiques et analogues (CEI 61095:2009)

Elektromechanische Schütze für Hausinstallationen und ähnliche Zwecke (IEC 61095:2009)

This European Standard was approved by CENELEC on 2009-03-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: avenue Marnix 17, B - 1000 Brussels

Foreword

The text of document 17B/1640/FDIS, future edition 2 of IEC 61095, prepared by SC 17B, Low-voltage switchgear and controlgear, of IEC TC 17, Switchgear and controlgear, in conjunction with SC 23E, Circuit-breakers and similar equipment for household use, of IEC TC 23, Electrical accessories, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61095 on 2009-03-01.

This European Standard supersedes EN 61095:1993 + corrigendum March 1993 + A1:2000 + corrigendum April 2001.

EN 61095:2009 includes the following significant technical changes with respect to EN 61095:1993:

– deletion of switching overvoltages requirements;

– addition of a new utilization category AC-7c: switching of compensated electric discharge lamp control;

– measuring of U_{imp} required, but the marking is not required if U_{imp} equal to 4 kV;

– improvement regarding marking concerning direction of movement;

– improvement of dielectric properties;

– test of resistance to humidity referred to EN 60068-2-78 instead of HD 323.2.3 S2;

– amendment to Table B.1 regarding test sequences;

– deletion of Table F.2 regarding the correspondence between the nominal voltage of the supply system and the contactor rated impulse withstand voltage;

– addition of a new Annex H (normative): degrees of protection of enclosed contactor;

– addition of a new Annex I (normative): requirements and tests for equipment with protective separation.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2009-12-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2012-03-01

Annex ZA has been added by CENELEC.

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Endorsement notice

The text of the International Standard IEC 61095:2009 was approved by CENELEC as a European Standard without any modification.

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Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60028	1925	International standard of resistance for copper	-	-
IEC 60050-151	2001	International Electrotechnical Vocabulary (IEV) - Part 151: Electrical and magnetic devices	-	-
IEC 60050-441 A1	1984 2000	International Electrotechnical Vocabulary (IEV) - Chapter 441: Switchgear, controlgear and fuses	-	-
IEC 60050-604 A1	1987 1998	International Electrotechnical Vocabulary (IEV) - Chapter 604: Generation, transmission and distribution of electricity - Operation	-	-
IEC 60050-826	2004	International Electrotechnical Vocabulary (IEV) - Part 826: Electrical installations	-	-
IEC 60068-2-78	2001	Environmental testing - Part 2-78: Tests - Test Cab: Damp heat, steady state	EN 60068-2-78	2001
IEC 60073	2002	Basic and safety principles for man-machine interface, marking and identification - Coding principles for indicators and actuators	EN 60073	2002
IEC 60085	2007	Electrical insulation - Thermal evaluation and designation	EN 60085	2008
IEC 60099-1 (mod) A1	1991 1999	Surge arresters - Part 1: Non-linear resistor type gapped surge arresters for a.c. systems	EN 60099-1 A1	1994 1999
IEC 60112	2003	Method for the determination of the proof and the comparative tracking indices of solid insulating materials	EN 60112	2003
IEC 60216	Series	Electrical insulating materials - Properties of thermal endurance	EN 60216	Series
IEC 60364-4-44	2007	Low voltage electrical installations - Part 4-44: Protection for safety - Protection against voltage disturbances and electromagnetic disturbances	-	-
IEC 60417	Data-base	Graphical symbols for use on equipment	-	-

Publication	Year	Title	EN/HD	Year
IEC 60445 (mod)	2006	Basic and safety principles for man-machine interface, marking and identification - Identification of equipment terminals and conductor terminations	EN 60445	2007
IEC 60447	2004	Basic and safety principles for man-machine interface, marking and identification - Actuating principles	EN 60447	2004
IEC 60529	1989	Degrees of protection provided by enclosures (IP Code)	EN 60529 + corr. May	1991 1993
A1	1999		A1	2000
IEC 60664-1	2007	Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests	EN 60664-1	2007
IEC 60695-2-10	2000	Fire hazard testing - Part 2-10: Glowing/hot-wire based test methods - Glow-wire apparatus and common test procedure	EN 60695-2-10	2001
IEC 60695-2-11	2000	Fire hazard testing - Part 2-11: Glowing/hot-wire based test methods - Glow-wire flammability test method for end-products	EN 60695-2-11	2001
IEC 60695-11-10 A1	1999 2003	Fire hazard testing - Part 11-10: Test flames - 50 W horizontal and vertical flame test methods	EN 60695-11-10 A1	1999 2003
IEC 60947-1	2007	Low-voltage switchgear and controlgear - Part 1: General rules	EN 60947-1	2007
IEC 60947-4-1 A1 A2	2000 2002 2005	Low-voltage switchgear and controlgear - Part 4-1: Contactors and motor-starters - Electromechanical contactors and motor-starters	EN 60947-4-1 A1 A2	2001 2002 2005
IEC 60947-5-1	2003	Low-voltage switchgear and controlgear - Part 5-1: Control circuit devices and switching elements - Electromechanical control circuit devices	EN 60947-5-1 + corr. July	2004 2005
IEC 61140 A1 (mod)	2001 2004	Protection against electric shock - Common aspects for installation and equipment	EN 61140 A1	2002 2006
IEC 61180	Series	High-voltage test techniques for low-voltage equipment	EN 61180	Series
ISO 2039-2	1987	Plastics - Determination of hardness - Part 2: Rockwell hardness	EN ISO 2039-2	1999
ISO 7000	2004	Graphical symbols for use on equipment - Index and synopsis	-	-

CONTENTS

INTRODUCTION

This International Standard gives requirements for contactors household and similar purposes, including contactors for distribution control in buildings.

Contactors for such purposes have particular requirements which include test sequences and sampling plans to facilitate testing.

Contactors according to this standard are limited in the range of operational currents and operational voltages to values appropriate to the applications. Such contactors are for use in circuits of limited prospective short-circuit fault current for which they need to be co-ordinated with an appropriate short-circuit protective device to provide suitable co-ordination.

This standard defines in a single document the specific utilization category for a described application and states the relevant requirements. As far as possible, it is in line with the requirements contained in IEC 60947-4-1 "Electromechanical contactors and motor-starters".

This standard also applies to contactors which are components of an appliance, unless otherwise stated in the standard covering the relevant appliance.

ELECTROMECHANICAL CONTACTORS FOR HOUSEHOLD AND SIMILAR PURPOSES

1 Scope

This International Standard applies to electromechanical air break contactors for household and similar purposes provided with main contacts intended to be connected to circuits the rated voltage of which does not exceed 440 V a.c. (between phases) with rated operational currents less than or equal to 63 A for utilization category AC-7a and 32 A for utilization categories AC-7b and AC-7c, and rated conditional short-circuit current less than or equal to 6 kA.

The contactors dealt with in this standard are not normally designed to interrupt short-circuit currents. Therefore, suitable short-circuit protection (see 9.3.4) shall form part of the installation.

This standard does not apply to

– contactors complying with IEC 60947-4-1;
– semiconductor contactors;
– contactors designed for special applications;
– auxiliary contacts of contactors. These are dealt with in IEC 60947-5-1.

This standard states

1) the characteristics of contactors.
2) the conditions with which contactors shall comply with reference to:
   a) their operation and behaviour;
   b) their dielectric properties;
   c) the degrees of protection provided by their enclosures, where applicable;
   d) their construction;
   e) their electromagnetic compatibility characteristics.
3) the tests intended for confirming that these conditions have been met, and the methods to be adopted for these tests.
4) the test sequences and the number of samples.
5) the information to be given with contactors or in the manufacturer's literature.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60028:1925, *International standard of resistance for copper*

IEC 60050-151:2001, *International Electrotechnical Vocabulary (IEV) – Part 151: Electrical and magnetic devices*

IEC 60050-441:1984, *International Electrotechnical Vocabulary (IEV) – Chapter 441: Switchgear, controlgear and fuses*
Amendment 1 (2000)

IEC 60050-604:1987, *International Electrotechnical Vocabulary (IEV) – Chapter 604: Generation, transmission and distribution of electricity – Operation*
Amendment 1 (1998)

IEC 60050-826:2004, *International Electrotechnical Vocabulary (IEV) – Part 826: Electrical installations*

IEC 60068-2-78:2001, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60073:2002, *Basic and safety principles for man-machine interface, marking and identification – Coding principles for indicators and actuators*

IEC 60085:2007, *Electrical insulation – Thermal evaluation and designation*

IEC 60099-1:1991, *Surge arresters – Part 1: Non-linear resistor type gapped surge arresters for a.c. systems*
Amendment 1 (1999)

IEC 60112:2003, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

IEC 60216 (all parts), *Electrical insulating materials – Properties of thermal endurance*

IEC 60364-4-44:2007, *Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances*

IEC 60417-DB: 2007[1], *Graphical symbols for use on equipment*

IEC 60445:2006, *Basic and safety principles for man-machine interface, marking and identification – Identification of equipment terminals and conductor terminations*

IEC 60447:2004, *Basic and safety principles for man-machine interface, marking and identification – Actuating principles*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*
Amendment 1 (1999)

IEC 60664-1:2007, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

IEC 60695-2-10:2000, *Fire hazard testing – Part 2-10: Glowing/hot-wire based test methods – Glow-wire apparatus and common test procedure*

IEC 60695-2-11:2000, *Fire hazard testing – Part 2-11: Glowing/hot-wire based test methods – Glow-wire flammability test method for end-products*

IEC 60695-11-10:1999, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*
Amendment 1 (2003)

IEC 60947-1:2007, *Low-voltage switchgear and controlgear – Part 1: General rules*

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1 “DB” refers to the IEC on-line database.

IEC 60947-4-1:2000, *Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters*
Amendment 1 (2002)
Amendment 2 (2005)

IEC 60947-5-1:2003, *Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements – Electromechanical control circuit devices*

IEC 61140:2001, *Protection against electric shock – Common aspects for installation and equipment*
Amendment 1 (2004)

IEC 61180 (all parts), *High-voltage test techniques for low-voltage equipment*

ISO 7000:2004, *Graphical symbols for use on equipment – Index and synopsis*

ISO 2039-2:1987, *Plastics – Determination of hardness – Part 2: Rockwell hardness*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 General terms

3.1.1
over-current
current exceeding the rated current

[IEV 441-11-06]

3.1.2
short-circuit
accidental or intentional conductive path between two or more conductive parts forcing the electric potential differences between these conductive parts to be equal to or close to zero

[IEV 151-12-04]

3.1.3
short-circuit current
over-current resulting from a short circuit due to a fault or an incorrect connection in an electric circuit

[IEV 441-11-07]

3.1.4
overload
operating conditions in an electrically undamaged circuit which cause an over-current

[IEV 441-11-08]

3.1.5
overload current
over-current occurring in an electrically undamaged circuit

3.1.6
ambient air temperature
temperature, determined under prescribed conditions, of the air surrounding the complete switching device or fuse

NOTE For switching devices or fuses installed inside an enclosure, it is the temperature of the air outside the enclosure.

[IEV 441-11-13]

3.1.7
conductive part
part which is capable of conducting current although it may not necessarily be used for carrying service current

[IEV 441-11-09]

3.1.8
exposed conductive part
conductive part which can readily be touched and which is not normally alive, but which may become alive under fault conditions

NOTE Typical exposed conductive parts are walls of enclosures, operating handles, etc.

[IEV 441-11-10]

3.1.9
electric shock
physiological effect resulting from an electric current through a human or animal body

[IEV 826-12-01]

3.1.10
live part
conductor or conductive part intended to be energized in normal operation, including a neutral conductor, but by convention not a PEN conductor or PEM conductor or PEL conductor

NOTE This concept does not necessarily imply a risk of electric shock.

[IEV 826-12-08]

3.1.11
protective conductor (identification: PE)
conductor provided for purposes of safety, for example protection against electric shock

NOTE In an electrical installation, the conductor identified PE is normally also considered as protective earthing conductor.

[IEV 826-13-22]

3.1.12
neutral conductor
conductor electrically connected to the neutral point and capable of contributing to the distribution of electric energy

[IEV 826-14-07]

3.1.13
PEN conductor
conductor combining the functions of both a protective earthing conductor and a neutral conductor

[IEV 826-13-25]

3.1.14
PEM conductor
conductor combining the functions of both a protective earthing conductor and a mid-point conductor

[IEV 826-13-26]

3.1.15
PEL conductor
conductor combining the functions of both a protective earthing conductor and a line conductor

[IEV 826-13-27]

3.1.16
enclosure
part providing a specified degree of protection of equipment against certain external influences and a specified degree of protection against approach to or contact with live parts and moving parts

[IEV 441-13-01, modified]

NOTE This definition is similar to IEV 441-13-01, which applies to assemblies.

3.1.17
integral enclosure
enclosure which forms an integral part of the equipment

3.1.18
utilization category (for a switching device or a fuse)
combination of specified requirements related to the condition in which the switching device or the fuse fulfils its purpose, selected to represent a characteristic group of practical applications

NOTE The specified requirements may concern e.g. the values of making capacities (if applicable), breaking capacities and other characteristics, the associated circuits and the relevant conditions of use and behaviour.

[IEV 441-17-19]

3.2 Switching devices

3.2.1
switching device
device designed to make or break the current in one or more electric circuits

[IEV 441-14-01]

NOTE A switching device may perform one or both of these operations.

3.2.2
mechanical switching device
switching device designed to close and open one or more electric circuits by means of separable contacts

NOTE Any mechanical switching device may be designated according to the medium in which its contacts open and close, e.g. air, SF_6, oil.

[IEV 441-14-02]

3.2.3
semiconductor switching device
switching device designed to make and/or break the current in an electric circuit by means of the controlled conductivity of a semiconductor

NOTE This definition differs from IEV 441-14-03 since a semiconductor switching device is also designed for breaking the current.

[IEV 441-14-03, modified]

3.2.4
fuse
device that, by the fusing of one or more of its specifically designed and proportioned components, opens the circuit in which it is inserted by breaking the current when this exceeds a given value for a sufficient time. The fuse comprises all the parts that form the complete device

[IEV 441-18-01]

3.2.5
circuit-breaker
mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also making, carrying for a specified time and breaking currents under specified abnormal circuit conditions such as those of short circuit

[IEV 441-14-20]

3.2.6
(mechanical) contactor
mechanical switching device having only one position of rest, operated otherwise than by hand, capable of making, carrying and breaking currents under normal circuit conditions including operating overload conditions

[IEV 441-14-33]

NOTE 1 The term "operated otherwise than by hand" means that the device is intended to be controlled and kept in working position from one or more external supplies.

NOTE 2 In French, a contactor the main contacts of which are closed in the position of rest is usually called "rupteur". The word "rupteur" has no equivalent in the English language.

NOTE 3 A contactor is usually intended to operate frequently.

3.2.7
electromagnetic contactor
contactor, in which the force for closing the normally open main contacts or opening the normally closed main contacts is provided by an electromagnet

3.2.8
latched contactor
contactor, the moving elements of which are prevented by means of a latching arrangement from returning to the position of rest when the operating means are de-energized

NOTE 1 The latching, and the release of the latching, may be mechanical, electromagnetic, pneumatic, etc.

NOTE 2 Because of the latching, the latched contactor actually acquires a second position of rest and, according to 3.2.6 is not, strictly speaking, a contactor. However, since the latched contactor in both its utilization and its design is more closely related to contactors in general than to any other classification of switching device, it is considered proper to require that it complies with the specifications for contactors wherever they are appropriate.

[IEV 441-14-34]

3.2.9
semiconductor contactor
solid state contactor
device which performs the function of a contactor by utilizing a semiconductor switching device

NOTE A semiconductor contactor may also contain mechanical switching devices.

3.2.10
pilot switch
non-manual control switch actuated in response to specified conditions of an actuating quantity

NOTE The actuating quantity may be pressure, temperature, velocity, liquid level, elapsed time, etc.

[IEV 441-14-48]

3.2.11
push-button
control switch having an actuator intended to be operated by force exerted by a part of the human body, usually the finger or palm of the hand, and having stored energy (spring) return

[IEV 441-14-53]

3.2.12
short-circuit protective device
SCPD
device intended to protect a circuit or parts of a circuit against short-circuit currents by interrupting them

3.2.13
surge arrester
device designed to protect the electrical apparatus from high transient over-voltages and to limit the duration and frequently the amplitude of the follow-on current

[IEV 604-03-51]

3.3 Parts of switching devices

3.3.1
pole (of a switching device)
portion of a switching device associated exclusively with one electrically separated conducting path of its main circuit and excluding those portions which provide a means for mounting and operating all poles together

NOTE A switching device is called single-pole if it has only one pole. If it has more than one pole, it may be called multipole (two-pole, three-pole, etc.) provided the poles are or can be coupled in such a manner as to operate together.

[IEV 441-15-01]

3.3.2
main circuit (of a switching device)
all the conductive parts of a switching device included in the circuit which it is designed to close or open

[IEV 441-15-02]

3.3.3
control circuit (of a switching device)
all the conductive parts (other than the main circuit) of a switching device which are included in a circuit used for the closing operation or opening operation, or both, of the device

[IEV 441-15-03]

3.3.4
auxiliary circuit (of a switching device)
all the conductive parts of a switching device which are intended to be included in a circuit other than the main circuit and the control circuits of the device

NOTE Some auxiliary circuits fulfil supplementary functions such as signalling, interlocking, etc., and, as such, they may be part of the control circuit of another switching device.

[IEV 441-15-04]

3.3.5
contact (of a mechanical switching device)
conductive parts designed to establish circuit continuity when they touch and which, due to their relative motion during an operation, open or close a circuit or, in the case of hinged or sliding contacts, maintain circuit continuity

[IEV 441-15-05]

3.3.6
contact (piece)
one of the conductive parts forming a contact

[IEV 441-15-06]

3.3.7
main contact
contact included in the main circuit of a mechanical switching device, intended to carry, in the closed position, the current of the main circuit

[IEV 441-15-07]

3.3.8
control contact
contact included in a control circuit of a mechanical switching device and mechanically operated by this device

[IEV 441-15-09]

3.3.9
auxiliary contact
contact included in an auxiliary circuit and mechanically operated by the switching device

[IEV 441-15-10]

3.3.10
auxiliary switch (of a mechanical switching device)
switch containing one or more control and/or auxiliary contacts mechanically operated by a switching device

[IEV 441-15-11]

3.3.11
"a" contact
make contact
control or auxiliary contact which is closed when the main contacts of the mechanical switching device are closed and open when they are open

[IEV 441-15-12]

3.3.12
"b" contact
break contact
control or auxiliary contact which is open when the main contacts of the mechanical switching device are closed and closed when they are open

[IEV 441-15-13]

3.3.13
release (of a mechanical switching device)
device, mechanically connected to a mechanical switching device, which releases the holding means and permits the opening or the closing of the switching device

[IEV 441-15-17]

NOTE A release can have instantaneous, time-delay, etc. operation.

3.3.14
actuating system (of a mechanical switching device)
whole of the operating means of a mechanical switching device which transmits the actuating force to the contact pieces

NOTE The operating means of an actuating system may be mechanical, electromagnetic, hydraulic, pneumatic, thermal, etc.

3.3.15
actuator
part of the actuating system to which an external actuating force is applied

NOTE The actuator may take the form of a handle, knob, push-button, roller, plunger, etc.

[IEV 441-15-22]

3.3.16
position indicating device
part of a mechanical switching device which indicates whether it is in the open, closed, or, where appropriate, earthed position

[IEV 441-15-25]

3.3.17
terminal
conductive part of a device provided for electrical connection to external circuits

3.3.18
screw-type terminal
terminal intended for the connection and disconnection of conductors or for the interconnection of two or more conductors, the connection being made, directly or indirectly, by means of screws or nuts of any kind

3.3.19
screwless-type terminal
terminal intended for the connection and disconnection of conductors or for the interconnection of two or more conductors, the connection being made, directly or indirectly, by means of springs, wedges, eccentrics or cones, etc.

3.3.20
thread-forming tapping screw
tapping screw having an uninterrupted thread. It is not a function of this thread to remove material from the hole

NOTE An example of a thread-forming tapping screw is shown in Figure 1.

3.3.21
thread-cutting tapping screw
tapping screw having an interrupted thread. The thread is intended to remove material from the hole

NOTE An example of a thread-cutting tapping screw is shown in Figure 2.

3.3.22
clamping unit
part of a terminal necessary for the mechanical clamping and the electrical connection of the conductor(s)

3.3.23
unprepared conductor
conductor which has been cut and the insulation of which has been removed for insertion into a terminal

NOTE A conductor, the shape of which is arranged for introduction into a terminal or the strands of which are twisted to consolidate the end is considered to be an unprepared conductor.

3.3.24
prepared conductor
conductor, the strands of which are soldered or the end of which is fitted with a cable lug, eyelet, etc.

3.4 Operation of switching devices

3.4.1
operation (of a mechanical switching device)
transfer of the moving contact(s) from one position to an adjacent position

NOTE 1 For a circuit-breaker, this may be a closing operation or an opening operation.

NOTE 2 If distinction is necessary, an operation in the electrical sense, e.g. make or break, is referred to as a switching operation, and an operation in the mechanical sense, e.g. close or open, is referred to as a mechanical operation.

[IEV 441-16-01]

3.4.2
operating cycle (of a mechanical switching device)
succession of operations from one position to another and back to the first position through all other positions, if any

[IEV 441-16-02]

3.4.3
operating setquence (of a mechanical switching device)
succession of specified operations with specified time intervals

[IEV 441-16-03]

3.4.4
automatic control
control of an operation without human intervention, in response to the occurrence of predetermined conditions

[IEV 441-16-05]

3.4.5
closing operation (of a mechanical switching device)
operation by which the device is brought from the open position to the closed position

[IEV 441-16-08]

3.4.6
opening operation (of a mechanical switching device)
operation by which the device is brought from the closed position to the open position

[IEV 441-16-09]

3.4.7
closed position (of a mechanical switching device)
position in which the predetermined continuity of the main circuit of the device is secured

[IEV 441-16-22]

3.4.8
open position (of a mechanical switching device)
position in which the predetermined dielectric withstand voltage requirements are satisfied between open contacts in the main circuit of the device

NOTE This definition differs from IEV 441-16-23 to meet the requirements of dielectric properties.

[IEV 441-16-23, modified]

3.4.9
position of rest (of a contactor)
position which the moving elements of the contactor take up when its electromagnet or its compressed-air device is not energized

[IEV 441-16-24]

3.4.10
inching
jogging
energizing a motor or solenoid repeatedly for short periods to obtain small movements of the driven mechanism

3.4.11
plugging
stopping or reversing a motor rapidly by reversing the motor primary connections while the motor is running

3.5 Characteristic quantities

3.5.1
nominal value
value of a quantity used to designate and identify a component, device, equipment, or system

NOTE The nominal value is generally a rounded value.

[IEV 151-16-09]

3.5.2
limiting value
in a specification of a component, device, equipment, or system, the greatest or smallest admissible value of a quantity

[IEV 151-16-10]

3.5.3
rated value
value of a quantity used for specification purposes, established for a specified set of operating conditions of a component, device, equipment, or system

[IEV 151-16-08]

3.5.4
rating
set of rated values and operating conditions

[IEV 151-16-11]

3.5.5
prospective current (of a circuit and with respect to a switching device or a fuse)
current that would flow in the circuit if each pole of the switching device or the fuse were replaced by a conductor of negligible impedance

NOTE The method to be used to evaluate and to express the prospective current is to be specified in the relevant publications.

[IEV 441-17-01]

3.5.6
prospective peak current
peak value of a prospective current during the transient period following initiation

NOTE The definition assumes that the current is made by an ideal switching device, i.e. with instantaneous transition from infinite to zero impedance. For circuits where the current can follow several different paths, e.g. polyphase circuits, it further assumes that the current is made simultaneously in all poles, even if only the current in one pole is considered.

[IEV 441-17-02]

3.5.7
maximum prospective peak current (of an a.c. circuit)
prospective peak current when initiation of the current takes place at the instant which leads to the highest possible value

NOTE For a multipole device in a polyphase circuit, the maximum prospective peak current refers to a single pole only.

[IEV 441-17-04]

3.5.8
breaking current (of a switching device or a fuse)
current in a pole of a switching device or in a fuse at the instant of initiation of the arc during a breaking process

[IEV 441-17-07]

NOTE For a.c. the current is expressed as the symmetrical r.m.s. value of the a.c. component.

3.5.9
breaking capacity (of a switching device or a fuse)
value of prospective current that a switching device or a fuse is capable of breaking at a stated voltage under prescribed conditions of use and behaviour

[IEV 441-17-08]

NOTE 1 The voltage to be stated and the conditions to be prescribed are dealt with in the relevant product standard.

NOTE 2 For a.c. the current is expressed as the symmetrical r.m.s. value of the a.c. component.

NOTE 3 For short-circuit breaking capacity, see 3.5.11.

3.5.10
making capacity (of a switching device)
value of prospective making current that a switching device is capable of making at a stated voltage under prescribed conditions of use and behaviour

[IEV 441-17-09]

NOTE 1 The voltage to be stated and the conditions to be prescribed are dealt with in the relevant product standard.

NOTE 2 For short-circuit making capacity, see 3.5.12.

3.5.11
short-circuit breaking capacity
breaking capacity for which the prescribed conditions include a short-circuit at the terminals of the switching device

[IEV 441-17-11]

3.5.12
short-circuit making capacity
making capacity for which prescribed conditions include a short circuit at the terminals of the switching device

[IEV 441-17-10]

3.5.13
joule integral (I^2t)
integral of the square of the current over a given time interval

$$I^2t = \int_{t_0}^{t_1} i^2 \, \mathrm{d}t$$

[IEV 441-18-23]

3.5.14
cut-off current
let-through current
maximum instantaneous value of current attained during the breaking operation of a switching device or a fuse

NOTE This concept is of particular importance when the switching device or the fuse operates in such a manner that the prospective peak current of the circuit is not reached.

[IEV 441-17-12]

3.5.15
applied voltage (for a switching device)
voltage which exists across the terminals of a pole of a switching device just before the making of the current

[IEV 441-17-24]

NOTE This definition applies to a single-pole device. For a multipole device it is the phase-to-phase voltage across the supply terminals of the device.

3.5.16
recovery voltage
voltage which appears across the terminals of a pole of a switching device or a fuse after the breaking of the current

[IEV 441-17-25]

NOTE 1 This voltage may be considered in two successive intervals of time, one during which a transient voltage exists, followed by a second one during which the power frequency voltage or the steady-state recovery voltage alone exists.

NOTE 2 This definition applies to a single-pole device. For a multipole device it is the phase-to-phase voltage across the supply terminals of the device.

3.5.17
transient recovery voltage
(TRV)
recovery voltage during the time in which it has a significant transient character

[IEV 441-17-26]

NOTE The transient voltage may be oscillatory or non-oscillatory or a combination of these depending on the characteristics of the circuit, the switching device or the fuse. It includes the voltage shift of the neutral of a polyphase circuit.

3.5.18
power-frequency recovery voltage
recovery voltage after the transient voltage phenomena have subsided

[IEV 441-17-27]

3.5.19
d.c. steady-state recovery voltage
recovery voltage in a d.c. circuit after the transient voltage phenomena have subsided, expressed by the mean value where ripple is present

[IEV 441-17-28]

3.5.20
clearance
distance between two conductive parts along a string stretched the shortest way between these conductive parts

[IEV 441-17-31]

3.5.21
creepage distance
shortest distance along the surface of an insulating material between two conductive parts

NOTE A joint between two pieces of insulating material is considered part of the surface.

3.5.22
working voltage
highest r.m.s. value of the a.c. voltage or the highest value of the d.c. voltage which may occur (locally) across any insulation at rated supply voltage, transients being disregarded, in open circuit conditions or under normal operating conditions

3.5.23
impulse withstand voltage
highest peak value of an impulse voltage, of prescribed form and polarity, which does not cause breakdown under specified conditions of test

3.5.24
power-frequency withstand voltage
r.m.s. value of a power-frequency sinusoidal voltage which does not cause breakdown under specified conditions of test

3.5.25
pollution
any addition of foreign matter, solid, liquid or gaseous (ionized gases) that may affect dielectric strength or surface resistivity

3.5.26
pollution degree (of environmental conditions)
conventional number based on the amount of conductive or hygroscopic dust, ionized gas or salt and on the relative humidity and its frequency of occurrence, resulting in hygroscopic absorption or condensation of moisture leading to reduction in dielectric strength and/or surface resistivity

NOTE 1 The pollution degree of the micro-environment to which equipment is exposed may be different from that of the macro-environment where the equipment is located because of protection offered by means such as an enclosure or internal heating to prevent absorption or condensation of moisture.

NOTE 2 For the purposes of this standard, the pollution degree is that of the micro-environment.

3.5.27
micro-environment (of a clearance or creepage distance)
ambient conditions which surround the clearance or creepage distance under consideration

NOTE The micro-environment of the creepage distance or clearance and not the environment of the equipment determines the effect on the insulation. The micro-environment may be better or worse than the environment of the equipment. It includes all factors influencing the insulation such as climatic and electromagnetic conditions, generation of pollution, etc.

3.5.28
over-voltage category (of a circuit or within an electrical system)
conventional number based on limiting (or controlling) the values of prospective transient over-voltages occurring in a circuit (or within an electrical system having different nominal voltages) and depending on the means employed to influence the over-voltages

NOTE In an electrical system, the transition from one over-voltage category to one of a lower category is obtained through appropriate means complying with interface requirements, such as an over-voltage protective device or a series-shunt impedance arrangement capable of dissipating, absorbing, or diverting the energy in the associated surge current, to lower the transient over-voltage value to that of the desired lower over-voltage category.

3.5.29
co-ordination of insulation
correlation of insulating characteristics of electrical equipment with the expected over-voltages and the characteristics of over-voltage protective devices on the one hand, and with the expected micro-environment and the pollution protective means on the other hand

3.5.30
homogeneous field
uniform field
electric field which has an essentially constant voltage gradient between electrodes, such as that between two spheres where the radius of each sphere is greater than the distance between them

3.5.31
inhomogeneous field
non-uniform field
electric field which does not have an essentially constant voltage gradient between electrodes

3.5.32
tracking
progressive formation of conducting paths which are produced on the surface of a solid insulating material, due to the combined effects of electric stress and electrolytic contamination on that surface

3.5.33
comparative tracking index
CTI
numerical value of the maximum voltage in volts at which a material withstands 50 drops of a test solution without tracking

NOTE 1 The value of each test voltage and the CTI should be divisible by 25.

NOTE 2 This definition is based on 3.5 of IEC 60112:2003.

4 Classification

Subclause 5.2 gives all data which may be used as criteria for classification.

5 Characteristics of contactors

5.1 Summary of characteristics

The characteristics shall be stated in the following terms, where such terms are applicable:

– type of contactor (see 5.2);
– rated and limiting values for main circuits (see 5.3);
– utilization category (see 5.4);
– control circuits (see 5.5);
– auxiliary circuits (see 5.6);
– co-ordination with short-circuit protective devices (see 5.7).

5.2 Type of contactor

The following shall be stated (see also Clause 6):

5.2.1 Number of poles

5.2.2 Method of control

– automatic (by pilot switch or sequence control);
– non-automatic (e.g. by hand operation or by push-buttons);
– semi-automatic (i.e. partly automatic, partly non-automatic).

5.3 Rated and limiting values for main circuits

5.3.1 General

The rated values established for a contactor shall be stated in accordance with 5.3.2 to 5.4 and 5.7, but it may not be necessary to establish all the listed values.

5.3.2 Rated voltages

A contactor is defined by the following rated voltages.

5.3.2.1 Rated operational voltage (U_e)

A rated operational voltage of a contactor is a value which, combined with a rated operational current, determines the application of the contactor and to which the relevant tests and the utilization categories are referred.

For a single-pole contactor, the rated operational voltage is generally stated as the voltage across the pole.

For a multipole contactor, it is generally stated as the voltage between phases.

NOTE 1 A contactor may be assigned a number of combinations of rated operational voltages and rated operational currents or powers for different duties and utilization categories.

NOTE 2 A contactor may be assigned a number of rated operational voltages and associated making and breaking capacities for different duties and utilization categories.

NOTE 3 Attention is drawn to the fact that the operational voltage may differ from the working voltage (see 3.5.22) within a contactor.

5.3.2.2 Rated insulation voltage (U_i)

The rated insulation voltage of a contactor is the value of voltage to which dielectric tests voltage and creepage distances are referred.

In no case shall the maximum value of the rated operational voltage exceed that of the rated insulation voltage.

NOTE For contactors without a specified rated insulation voltage, the highest value of the rated operational voltage is considered to be the rated insulation voltage.

5.3.2.3 Rated impulse withstand voltage (U_{imp})

The peak value of an impulse voltage of prescribed form and polarity which the contactor is capable of withstanding without failure under specified conditions of test and to which the values of the clearances are referred.

The rated impulse withstand voltage of a contactor shall be equal to or higher than the values stated for the transient over-voltages occurring in the circuit in which the contactor is fitted.

NOTE Preferred values of rated impulse withstand voltage are given in Table 16.

5.3.3 Currents or powers

A contactor is defined by the following currents.

5.3.3.1 Conventional free air thermal current (I_{th})

The conventional free air thermal current is the maximum value of test current to be used for temperature-rise tests of an unenclosed contactor in free air (see 9.3.3.3).

The value of the conventional free air thermal current shall be at least equal to the maximum value of the rated operational current (see 5.3.3.3) of the unenclosed contactor in eight-hour duty (see 5.3.5.1).

Free air is understood to be air in normal indoor conditions, reasonably free from draughts and external radiation.

NOTE 1 This current is not a rating and is not mandatorily marked on the contactor.

NOTE 2 An unenclosed contactor is a contactor supplied by the manufacturer without an enclosure or a contactor supplied by the manufacturer with an integral enclosure which is not normally intended to be the sole contactor protective enclosure.

5.3.3.2 Conventional enclosed thermal current (I_{the})

The conventional enclosed thermal current is the value of current stated by the manufacturer to be used for the temperature-rise tests of the contactor when mounted in a specified enclosure. Such tests shall be in accordance with 9.3.3.3 and are mandatory if the contactor is described as an enclosed contactor in the manufacturer's catalogues and normally intended for use with one or more enclosures of specified type and size (see Note 2).

The value of the conventional enclosed thermal current shall be at least equal to the maximum value of the rated operational current (see 5.3.3.3) of the enclosed contactor in eight-hour duty (see 5.3.5.1).

If the contactor is normally intended for use in unspecified enclosures, the test is not mandatory if the test for conventional free air thermal current (I_{th}) has been made. In this case, the manufacturer shall be prepared to give guidance on the value of the enclosed thermal current or the derating factor.

NOTE 1 This current is not a rating and is not mandatorily marked on the contactor.

NOTE 2 An enclosed contactor is a contactor normally intended for use with a specified type and size of enclosure or intended for use with more than one type of enclosure.

5.3.3.3 Rated operational currents (I_e) or rated operational powers

A rated operational current of a contactor is stated by the manufacturer and takes into account the rated operational voltage (see 5.3.2.1), the conventional free air or enclosed thermal current, the rated frequency (see 5.3.4), the rated duty (see 5.3.5), the utilization category (see 5.4) and the type of protective enclosure, if any.

In the case of a contactor for the direct switching of individual motors, the indication of a rated operational current may be replaced or supplemented by an indication of the maximum rated power output, at the rated operational voltage considered, of the motor for which the contactor is intended. The manufacturer shall be prepared to state the relationship assumed between the operational current and the operational power.

5.3.4 Rated frequency

The supply frequency for which a contactor is designed and to which the other characteristic values correspond.

NOTE The same contactor may be assigned a number or a range of rated frequencies.

5.3.5 Rated duties

The rated duties considered as normal are the following.

5.3.5.1 Eight-hour duty (continuous duty)

A duty in which the main contacts of a contactor remain closed while carrying a steady current long enough for the contactor to reach thermal equilibrium but not for more than eight hours without interruption.

NOTE 1 This is the basic duty on which the conventional thermal currents I_{th} and I_{the} of the contactor are determined.

NOTE 2 Interruption means breaking the current by operating the contactor.

5.3.5.2 Intermittent periodic duty or intermittent duty

A duty with on-load periods, during which the main contacts of a contactor remain closed, having a definite relation to off-load periods, both periods being too short to allow the contactor to reach thermal equilibrium.

Intermittent duty is characterized by the value of the current, the duration of the current flow and by the on-load factor which is the ratio of the in-service period to the entire period, often expressed as a percentage.

According to the number of operating cycles which they are capable of carrying out per hour, contactors are divided into the following preferred classes:

- class 1: 1 operating cycle per hour;
- class 3: 3 operating cycles per hour;
- class 12: 12 operating cycles per hour;
- class 30: 30 operating cycles per hour;
- class 120: 120 operating cycles per hour;
- class 300: 300 operating cycles per hour;
- class 1 200: 1 200 operating cycles per hour.

A contactor intended for intermittent duty may be designated by the characteristics of intermittent duty.

EXAMPLE An intermittent duty comprising a current flow of 32 A for 2 min within every 5 min may be stated as: 32 A, class 12, 40 %.

5.3.5.3 Temporary duty

Duty in which the main contacts of a contactor remain closed for periods insufficient to allow the contactor to reach thermal equilibrium, the on-load periods being separated by off-load periods of sufficient duration to restore equality of temperature with the cooling medium.

5.3.5.4 Periodic duty

A type of duty in which operation, whether at constant or variable load, is regularly repeated.

5.3.6 Normal load and overload characteristics

This subclause gives general requirements concerning ratings under normal load and overload conditions.

Detailed requirements are given in 8.2.4.

5.3.6.1 Ability to withstand motor switching overload currents

A contactor intended for switching motors shall be capable of withstanding the thermal stresses due to starting and accelerating a motor to normal speed and due to operating overloads.

Requirements to meet these conditions are given in 8.2.4.4.

5.3.6.2 Rated making capacity

Requirements for the various utilization categories (see 5.4) are given in 8.2.4.2. The rated making and breaking capacities are only valid when the contactor is operated in accordance with the requirements of 8.2.1.1 and 8.2.1.2.

5.3.6.3 Rated breaking capacity

Requirements for the various utilization categories (see 5.4) are given in 8.2.4.2. The rated making and breaking capacities are only valid when the contactor is operated in accordance with the requirements of 8.2.1.1 and 8.2.1.2.

5.3.6.4 Conventional operational performance

Specified as a series of making and breaking operations in 8.2.4.3.

5.3.7 Rated conditional short-circuit current

The rated conditional short-circuit current of a contactor is the value of prospective current stated by the manufacturer, that the contactor, protected by a short-circuit protective device specified by the manufacturer, can withstand satisfactorily for the operating time of this device under the test conditions specified in 9.3.4.

The details of the specified short-circuit protective device shall be stated by the manufacturer.

NOTE The rated conditional short-circuit current is expressed by the r.m.s. value of the a.c. component.

5.4 Utilization category

5.4.1 General

The utilization category of a contactor defines the intended application and is characterized by one or more of the following service conditions:

– current(s), expressed as multiple(s) of the rated operational current;
– voltage(s), expressed as multiple(s) of the rated operational voltage;
– power-factor.

The standard utilization categories are given in Table 1.

Each utilization category is characterized by the values of the currents, voltages, power-factors and other data of Table 7 and Table 9 and by the test conditions specified in this standard.

It is therefore unnecessary to specify separately the rated making and breaking capacities as these values depend directly on the utilization category as shown in Table 7.

Unless otherwise stated, contactors of utilization category AC-7b are designed on the basis of the starting characteristics of the motors compatible with the making capacities of Table 7. When the starting current of a motor, with stalled rotor, exceeds these values, the operational current should be decreased accordingly.

5.4.2 Assignment of utilization categories based on the results of tests

A contactor which has been tested for one utilization category or at any combination of parameters (such as highest operational voltage and current, etc.) can be assigned another utilization category without testing provided that the test currents, voltages, power-factors, number of operating cycles, ON and OFF times given in Table 7 and Table 9 and the test circuit for the assigned utilization category are not more severe than those at which the contactor has been tested and the temperature-rise has been verified at a current not less than the highest assigned rated operational current in continuous duty.

Table 1 – Utilization categories

Utilization categories [a]	Typical applications
AC-7a	Slightly inductive loads
AC-7b	Motor loads [b]
AC-7c	Switching of compensated electric discharge lamp control [c]

[a] Contactors may have other utilization categories, in which case they shall comply with the requirements of IEC 60947-4-1 for such categories.

[b] The AC-7b category may be used for occasional inching (jogging) or plugging for limited time periods; during such limited time periods the number of operations should not exceed 5/min or more than 10 in a 10-minute period.

[c] This category is similar to a capacitive switching category AC-6b as defined in IEC 60947-4-1 for the switching of capacitor banks, the characteristic being very dependant on the capacitance value of the lamp circuit.

5.5 Control circuits

The characteristics of control circuits are:

– kind of current;
– rated frequency;
– rated control circuit voltage U_c (nature and frequency);
– rated control supply voltage U_s (nature and frequency), where applicable;
– suitability to be connected to SELV circuits.

NOTE A distinction has been made above between the control circuit voltage, which would appear across the "a" contacts (see 3.3.11) in the control circuit, and the control supply voltage, which is the voltage applied to the input terminals of the control circuit of the contactor and which may be different from the control circuit voltage owing to the presence of built-in transformers, rectifiers, resistors, etc.

The rated control circuit voltage and rated frequency, if any, are the values on which the operating and temperature-rise characteristics of the control circuit are based.

5.6 Auxiliary circuits

The characteristics of auxiliary circuits are the number and kind of contacts ("a" contact, "b" contact, etc.) in each of these circuits and their ratings according to IEC 60947-5-1.

The characteristics of auxiliary contacts and switches shall comply with the requirements of that standard.

5.7 Co-ordination with short-circuit protective devices

Contactors are characterized by the type, ratings and characteristics of the short-circuit protective devices (SCPD) to be used to provide adequate protection of the contactor against short-circuit currents. Requirements are given in 8.2.5.

6 Product information

6.1 Nature of information

The following information shall be given by the manufacturer.

6.1.1 Identification

a) the manufacturer's name or trade mark;
b) type designation or serial number;

c) number of this standard, if the manufacturer claims compliance.

6.1.2 Characteristics, basic rated values and utilization

d) rated operational voltages (see 5.3.2.1);

e) utilization category and rated operational currents (or rated powers), at the rated operational voltage (see 5.3.3.3 and 5.4);

f) value of the rated frequency/frequencies, e.g.: 50 Hz or 50 Hz/60 Hz;

g) rated duty with indication of the class of intermittent duty, if any (see 5.3.5).

Associated values:

h) rated making and breaking capacities. These indications may be replaced, where applicable, by the indication of the utilization category (see Table 7);

Safety and installation:

i) rated insulation voltage (see 5.3.2.2);

j) rated impulse withstand voltage (see 5.3.2.3), the marking of U_{imp} is not required if equal to 4 kV;

k) IP code, in case of an enclosed contactor (see 8.1.11);

l) pollution degree (see 7.1.3.2);

m) rated conditional short-circuit current (see 5.3.7) and the type, current rating and characteristics of the associated SCPD;

n) vacant.

Control circuits (see 5.5):

The following information concerning control circuits shall be placed either on the coil or on the contactor:

o) rated control circuit voltage (U_c), nature of current and rated frequency;

p) if necessary nature of current, rated frequency and rated control supply voltage (U_s);

For contactors, the control circuit of which is intended to be connected to a SELV supply:

q) suitability of the control circuit to be connected to a SELV supply, the main circuit being supplied with a voltage having a value greater than that of the SELV circuit.

Auxiliary circuits:

r) ratings of auxiliary circuits (see 5.6).

6.2 Marking

Markings shall be indelible and easily legible.

Marking of the manufacturer's name or trade mark and type designation or serial number is mandatory on the contactor, preferably on the nameplate if any, to enable complete data to be obtained from the manufacturer.

NOTE 1 In the USA and Canada, the rated operational voltage U_e may be marked as follows:

a) on equipment for use on three-phase – four-wire systems, by both the value of phase-to-earth voltage and that of phase-to-phase voltage, e.g. 277/480 V;

b) on equipment for use on three-phase – three-wire systems, by the value of phase-to-phase voltage, e.g. 480 V.

The following information shall be marked and visible after mounting:

– direction of movement of the actuator (see 8.1.5.3), if applicable;

– indication of the position of the actuator (see also 8.1.6.1 and 8.1.6.2);
– reference to this standard, if the manufacturer claims compliance.

The following information shall be marked and visible after wiring, before installation of covers or lids:

– for miniaturized contactors, symbol, colour code or letter code;
– terminal identification and marking (see 8.1.7.4);
– IP code and class of protection against electric shock, when applicable (marked preferably on the contactor as far as possible).

Markings shall not be placed on screws, removable washers or other removable parts.

Data under k) shall be indicated on the enclosure, if any.

Data under c) shall be indicated on the nameplate.

Data under d) to j) and l) to r) shall be included on the nameplate, or on the contactor, or in the manufacturer's published literature.

Marking of terminals shall be in accordance with Annex A of this standard.

NOTE 2 Additional utilization categories according to IEC 60947-4-1 may also be marked (see footnote a to Table 1 of this standard).

6.3 Instructions for installation, operation and maintenance

The manufacturer shall specify in his documents or catalogues the conditions, if any, for installation, operation and maintenance of the contactor during operation and after a fault.

If necessary, the instructions for the transport, installation and operation of the contactor shall indicate the measures that are of particular importance for the proper and correct installation, commissioning and operation of the contactor.

These documents shall indicate the recommended extent and frequency of maintenance, if any.

7 Normal service, mounting and transport conditions

7.1 Normal service conditions

Contactors complying with this standard shall be capable of operating under the following standard conditions.

7.1.1 Ambient air temperature

The ambient air temperature does not exceed +40 °C and its average over a period of 24 h does not exceed +35 °C.

The lower limit of the ambient air temperature is –5 °C.

Ambient air temperature is that existing in the vicinity of the contactor if supplied without enclosure, or in the vicinity of the enclosure if supplied with an enclosure.

Contactors intended to be used in ambient air temperatures above +40 °C (particularly in tropical countries) or below –5 °C shall either be specially designed or be used according to the information given in the manufacturer's catalogue.

7.1.2 Altitude

The altitude of the site of installation does not exceed 2 000 m.

For installations at higher altitudes, it is necessary to take into account the reduction of the dielectric strength and the cooling effects of the air.

Contactors intended to be so used shall be designed especially or used according to an agreement between manufacturer and user.

Information in the manufacturer's catalogue may take the place of such an agreement.

7.1.3 Atmospheric conditions

7.1.3.1 Humidity

The relative humidity of the air does not exceed 50 % at a maximum temperature of +40 °C. Higher relative humidities may be permitted at lower temperatures, e.g. 90 % at +20 °C. Special measures may be necessary in cases of occasional condensation due to variation in temperature.

NOTE The pollution degrees given in 7.1.3.2 define the environmental conditions more precisely.

7.1.3.2 Pollution degree

The pollution degree (see 3.5.26) refers to the environmental conditions for which the contactor is intended.

NOTE The micro-environment of the creepage distance or clearance and not the environment of the contactor determines the effect on the insulation. The micro-environment may be better or worse than the environment of the contactor. It includes all the factors influencing the insulation, such as climatic and electromagnetic conditions, generation of pollution, etc.

For contactors intended for use within an enclosure or provided with an integral enclosure, the pollution degree of the environment in the enclosure is applicable.

For the purposes of evaluating clearances and creepage distances, the following four degrees of pollution of the micro-environment are established (the clearances and creepage distances being according to the different pollution degrees given in Table 17 and Table 18).

Pollution degree 1:

No pollution or only dry, non-conductive pollution occurs.

Pollution degree 2:

Normally, only non-conductive pollution occurs. Occasionally, however, a temporary conductivity caused by condensation may be expected.

Pollution degree 3:

Conductive pollution occurs, or dry, non-conductive pollution occurs which becomes conductive due to condensation.

Pollution degree 4:

The pollution generates persistent conductivity caused, for instance, by conductive dust or by rain or snow.

Standard pollution degree of household and similar applications:

Contactors for household and similar applications are generally for use in a pollution degree 2 environment.

7.1.4 Normal electromagnetic environmental conditions

The normal electromagnetic environmental conditions are those which relate to low-voltage public networks such as residential, commercial and light industrial locations/installations.

7.2 Conditions during transport and storage

The conditions during transport and storage, e.g. temperature and humidity, are those defined in 7.1, except that, unless otherwise specified, the following temperature range applies during transport and storage: between –25 °C and +55 °C and, for short periods not exceeding 24 h, up to +70 °C.

7.3 Mounting

The contactor shall be mounted in accordance with the manufacturer's instructions.

8 Constructional and performance requirements

8.1 Constructional requirements

8.1.1 General

The contactor with its enclosure, if any, whether integral or not, shall be designed and constructed to withstand the stresses occurring during installation and normal use and, in addition, shall provide a specified degree of resistance to abnormal heat and fire.

NOTE An enclosed contactor is a contactor mounted in an enclosure, designed and dimensioned to contain one contactor only.

8.1.2 Materials

8.1.2.1 General

The suitability of materials used is verified by making the following tests on the contactor and/or, if not practicable, on parts taken from it.

– resistance to ageing (see 8.1.2.2)
– resistance to humidity (see 8.1.2.3)
– resistance to heat (see 8.1.2.4)
– resistance to abnormal heat and fire (see 8.1.2.5)
– resistance to rusting (see 8.1.2.6)

As far as resistance to heat, abnormal heat and fire hazard are concerned, priority shall be given to tests made on the contactor or on a suitable part taken from the contactor.

However, in certain cases, tests on materials may be used, for practical reasons, as an alternative to tests on the contactor.

8.1.2.2 Resistance to ageing

Contactors shall be resistant to ageing.

In general, it is only necessary to test contactors having (or supplied with) enclosures or parts of p.v.c. or similar thermoplastic material and parts of rubber such as sealing rings and gaskets.

Compliance is checked by inspection and, if necessary, by a test according to 9.2.2.1.

8.1.2.3 Resistance to humidity

The contactor shall be protected against the effects of humidity which may occur in normal service.

Compliance shall be verified by the test specified in 9.2.2.2.

8.1.2.4 Resistance to heat

All parts of enclosed, partially enclosed and unenclosed contactors intended to prevent access to live parts shall not be adversely affected by the highest temperature likely to be reached during normal service.

Compliance shall be verified by the tests specified in 9.2.2.3.1 and 9.2.2.3.2.

8.1.2.5 Resistance to abnormal heat and fire

Parts of insulating material which might be exposed to thermal stresses due to electrical effects, the deterioration of which might impair the safety of the contactor, shall not be adversely affected by abnormal heat or fire.

Compliance shall be verified by the test specified in 9.2.2.4.

If a test has to be made at more than one place on the same sample, care shall be taken to ensure that any deterioration caused by previous tests does not affect the test to be made. Small parts with surface dimensions not exceeding 14 mm × 14 mm are not subjected to the test.

8.1.2.6 Resistance to rusting

Ferrous parts of the contactor including enclosures and covers, but excluding pole faces of electromagnets, shall be protected against rusting.

Compliance shall be verified by the test specified in 9.2.2.5.

8.1.3 Strength of screws or nuts other than those on terminals which are intended to be operated during installation or maintenance

Screws or nuts intended to be operated during installation or maintenance, as recommended by the manufacturer, shall withstand the mechanical stresses occurring in normal service.

Thread-forming tapping screws and thread-cutting tapping screws intended only for mechanical assembly may be used provided they are supplied together with the piece in which they are intended to be inserted.

An example of a thread-forming tapping screw is shown in Figure 1. An example of a thread-cutting tapping screw is shown in Figure 2. In addition, thread-cutting tapping screws intended to be operated by the installer shall be captive with the relevant part of the accessory.

Screws or nuts which transmit contact pressure shall be in engagement with metal threads.

For electrical connections, no contact pressure shall be transmitted through insulating material other than ceramic or other material with characteristics not less suitable and compensated for any possible shrinkage or yielding.

Compliance shall be verified by inspection and by the test of 9.2.3.

8.1.4 Vacant

8.1.5 Actuator

8.1.5.1 General

The requirements of 8.1.5.2 and 8.1.5.3 apply to contactors provided with a manually operated actuator.

8.1.5.2 Insulation

The actuator of the contactor shall be insulated from the live parts for the rated insulation voltage and, if applicable, the rated impulse withstand voltage.

Moreover:

– if the activator is made of metal, it shall be capable of being satisfactorily connected to a protective conductor unless it is provided with additional reliable insulation;
– if it is made of or covered by insulating material, any internal metal part which might become accessible in the event of insulation failure shall also be insulated from live parts for the rated insulation voltage.

8.1.5.3 Direction of movement

The direction of operation for actuators of devices shall normally conform to IEC 60447. Where devices cannot conform to these requirements, e.g. due to special applications or alternative mounting positions, they shall be clearly marked such that there is no doubt as to the “I” and “O” positions and the direction of the operation.

8.1.5.4 Mounting

Actuators mounted on removable panels or opening doors shall be so designed that when the panels are replaced or the doors closed, the actuator will engage correctly with the associated mechanism.

8.1.6 Indication of the OFF and ON positions

8.1.6.1 Indicating means

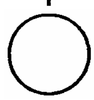
When a contactor is provided with means for indicating the closed and open positions, these positions shall be unambiguous and clearly indicated.

NOTE In the case of enclosed contactors, the indication may or may not be visible from the outside.

This is done by means of a position indicating device (see 3.3.16).

If symbols are used, they shall indicate the closed and open positions respectively, in accordance with IEC 60417:

60417-IEC-5007 ON (power)

60417-IEC-5008  OFF (power)

For contactors operated by means of two push-buttons, only the push-button designated for the opening operation shall be red or marked with the symbol "O".

Red colour shall not be used for any other push-button.

The colours of other push-buttons, illuminated push-buttons and indicator lights shall be in accordance with IEC 60073.

8.1.6.2 Indication by the actuator

When the actuator is used to indicate the position of the contacts, it shall automatically take up or stay in, when released, the position corresponding to that of the moving contacts; in this case, the actuator shall have two distinct rest positions corresponding to those of the moving contacts, but for automatic opening, a third distinct position of the actuator may be provided.

8.1.7 Terminals

8.1.7.1 Constructional requirements

All parts of terminals which maintain contact and carry current shall be of metal having adequate mechanical strength.

Terminal connections shall be such that the conductors may be connected by means of screws, springs or other equivalent means so as to ensure that the necessary contact pressure is maintained.

Terminals shall be so constructed that the conductors can be clamped between suitable surfaces without any significant damage either to conductors or terminals.

Terminals shall not allow the conductors to be displaced, or be displaced themselves in a manner detrimental to the operation of the contactor and the insulation voltage shall not be reduced below the rated values.

The requirements of this subclause shall be verified by the tests of 9.2.5.2, 9.2.5.3 and 9.2.5.4, as applicable.

NOTE North American countries have particular requirements for terminals suitable for aluminium conductors and marking to identify the use of aluminium conductors.

8.1.7.2 Connecting capacity

The manufacturer shall state the type (rigid – solid or stranded – or flexible), the minimum and the maximum cross-sections of conductors for which the terminal is suitable and, if applicable, the number of conductors simultaneously connectable to the terminal. However, the maximum cross-section shall not be smaller than that stated in 9.3.3.3 for the temperature-rise test and the terminal shall be suitable for conductors of the same type (rigid – solid or stranded – or flexible) at least two sizes smaller, as given in the appropriate column of Table 2.

Standard values of cross-sections of round copper conductors (both metric and AWG/MCM sizes) are shown in Table 2 which also gives the approximate relationship between ISO metric and AWG/MCM sizes.

Table 2 – Standard cross-sections of round copper conductors

ISO cross-sections mm²	AWG/MCM	
	Sizes	Equivalent cross-sections mm²
0,2	24	0,205
–	22	0,324
0,5	20	0,519
0,75	18	0,82
1	–	–
1,5	16	1,3
2,5	14	2,1
4	12	3,3
6	10	5,3
10	8	8,4
16	6	13,3
25	4	21,2
35	2	33,6
NOTE The dash, when it appears, counts as a size when considering connecting capacity.		

8.1.7.3 Connection

Terminals for connection to external conductors shall be readily accessible during installation.

Clamping screws and nuts shall not serve to fix any other component although they may hold the terminals in place or prevent them from turning.

8.1.7.4 Terminal identification and marking

Terminals shall be clearly and permanently identified in accordance with IEC 60445.

Terminals intended exclusively for the neutral conductor shall be identified by the letter "N", in accordance with IEC 60445.

The protective earth terminal shall be identified in accordance with 8.1.9.3.

Additional requirements for terminal identification and marking are given in Annex A.

8.1.8 Additional requirements for contactors provided with a neutral pole

When a contactor is provided with a pole intended only for connecting the neutral, this pole shall be clearly identified to that effect by the letter "N" (see 8.1.7.4).

A switched neutral pole shall not break before and shall not make after the other poles.

The value of the conventional thermal current shall be identical for all poles.

8.1.9 Provisions for earthing

8.1.9.1 Constructional requirements

The exposed conductive parts (e.g. chassis, framework and fixed parts of metal enclosures) other than those which cannot constitute a danger shall be electrically interconnected and connected to a protective earth terminal for connection to an earth electrode or to an external protective conductor.

This requirement can be met by the normal structural parts providing adequate electrical continuity and applies whether the contactor is used on its own or incorporated in an assembly.

Exposed conductive parts are not considered to constitute a danger if they cannot be touched on large areas or grasped with the hand or if they are of small size (approximately 50 mm × 50 mm) or are so located as to exclude any contact with live parts.

Examples of these are screws, rivets, nameplates, transformer cores, electromagnets and certain parts of releases, irrespective of their size.

8.1.9.2 Protective earth terminal

The protective earth terminal shall be readily accessible and so placed that the connection of the contactor to the earth electrode or to the protective conductor is maintained when the cover or any other removable part is removed.

The protective earth terminal shall be suitably protected against corrosion.

In the case of contactors with conductive structures, enclosures, etc., means shall be provided if necessary to ensure electrical continuity between the exposed conductive parts of the contactors and the metal sheathing of connecting conductors.

The protective earth terminal shall have no other function, except when it is intended to be connected to a PEN conductor. In that case, it shall also have the function of a neutral terminal in addition to meeting the requirements applicable to the protective earth terminal.

8.1.9.3 Protective earth terminal marking and identification

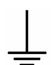
The protective earth terminal shall be clearly and permanently identified by its marking.

The identification shall be achieved by colour (green-yellow mark) or by the notation PE, or PEN as applicable, in accordance with Clause 7 of IEC 60445:2006, or, in the case of PEN, by a graphical symbol for use on contactors.

The graphical symbol to be used is symbol:

60417-IEC-5019  Protective earth (ground)

of IEC 60417.

NOTE The symbol  (60417-IEC-5017) previously recommended is progressively superseded by the preferred symbol 60417-IEC-5019 given above.

8.1.10 Enclosures

8.1.10.1 General

The following requirements are applicable only to enclosures supplied or intended to be used with the contactor.

8.1.10.2 Design

The enclosure shall be so designed that when it is opened and other protective means, if any, have been removed, all parts requiring access for installation and maintenance, as prescribed by the manufacturer, are readily accessible.

Sufficient space shall be provided inside the enclosure for the accommodation of external conductors from their point of entry into the enclosure to the terminals to ensure adequate connection.

The fixed parts of a metal enclosure shall be electrically connected to the other exposed conductive parts of the contactor and connected to a terminal which enables them to be earthed or connected to a protective conductor.

Under no circumstances shall a removable metal part of the enclosure be insulated from the part carrying the earth terminal when the removable part is in place.

The removable parts of the enclosure shall be firmly secured to the fixed parts by a device such that they cannot be accidentally loosened or detached owing to the effects of operation of the contactor or its vibrations.

For enclosures having a degree of protection IP1X up to and including IP4X, sufficient space shall be provided for establishing a drain-hole; such a drain-hole shall meet the requirements of IEC 60947-1.

Enclosures shall have adequate mechanical strength (see 8.1.12).

Furthermore, it shall not be possible to remove any cover of the enclosure without the use of a tool.

An integral enclosure is considered to be a non-removable part.

If the enclosure is used for mounting push-buttons, it shall not be possible to remove the buttons from the outside of the enclosure.

8.1.10.3 Insulation

If, in order to prevent accidental contact between a metallic enclosure and live parts, the enclosure is partly or completely lined with insulating material, this lining shall be securely fixed to the enclosure.

Compliance shall be verified by inspection.

8.1.11 Degrees of protection of enclosed contactors

IEC 60529 defines degrees of protection for enclosed equipment and guidance for the application of that standard to contactors is under consideration.

8.1.12 Resistance to impact

The external parts of enclosed, partially enclosed, and parts of unenclosed contactors, shall withstand impacts which might be expected in normal service.

Compliance shall be verified by the test specified in 9.2.6.

8.1.13 Durability of markings

The contactor shall be provided with a nameplate marked in a durable manner.

Compliance shall be verified by the test specified in 9.2.7.

8.2 Performance requirements

8.2.1 Operating conditions

8.2.1.1 General

The contactor shall be operated in accordance with the manufacturer's instructions.

The moving contacts of multipole contactors intended to make and break together shall be so mechanically coupled that all poles make and break substantially together (however, for switched neutral pole, see 8.1.8) whether operated manually or automatically.

8.2.1.2 Limits of operation

Contactors shall close satisfactorily at any value between 85 % and 110 % of their rated control supply voltage U_s. Where a range is declared, 85 % shall apply to the lower value and 110 % to the higher.

The limits between which contactors shall drop out and open fully are 75 % to 20 % of their rated control supply voltage U_s. Where a range is declared, 20 % shall apply to the higher value and 75 % to the lower.

Limits for closing are applicable after the coils have reached a stable temperature corresponding to indefinite application of 100 % U_s in an ambient temperature of +40 °C.

Limits for drop-out are applicable with the coil circuit resistance at –5 °C. This can be verified by calculation using values obtained at normal ambient temperature.

The limits apply at declared frequency, if any.

8.2.2 Temperature-rise

8.2.2.1 General

The requirements of 8.2.2, 8.2.2.2, 8.2.2.3 and 8.2.2.4 apply to contactors in clean, new condition.

The temperature-rises of the several parts of the contactor measured during a test carried out under the conditions specified in 9.3.3.3 shall not exceed the limiting values stated in Table 3 and in 8.2.2.2 and 8.2.2.3.

NOTE 1 Temperature-rises in normal service may differ from the test values, depending on the installation conditions and the size of connected conductors.

Table 3 – Temperature-rise limits for insulated coils in air

Classes of insulating materials	Temperature-rise limits (measured by resistance variation) K Coils in air
A	85
E	100
B	110
F	135
H	160

NOTE The insulation classification is that given in IEC 60085.

NOTE 2 The temperature-rise limits given in Table 3 and in Table 5 are applicable only if the ambient air temperature remains within the limits –5 °C, + 40 °C.

8.2.2.2 Terminals

The temperature-rise of terminals shall not exceed the values stated in Table 4.

Table 4 – Temperature-rise limits of terminals

Terminal materials	Temperature-rise limits K [a]
Bare copper	60
Bare brass	65
Tin-plated copper or brass	65
Silver- or nickel-plated copper or brass	70 [a]
Other metals	[b]

[a] The terminal temperature-rise limit of 70 K is based on the connection of PVC cables.

The use in service of connected conductors significantly smaller than those listed in Table 15 could result in higher terminal and internal part temperatures and such conductors should not be used without the manufacturer's consent since higher temperatures could lead to contactor failure.

[b] Temperature-rise limits to be based on service experience or life tests but not to exceed 65 K.

8.2.2.3 Accessible parts

The temperature-rise of accessible parts shall not exceed the values stated in Table 5.

Table 5 – Temperature-rise limits of accessible parts

Accessible parts	Temperature-rise limits [a] K
Manual operating means:	
Metallic	15
Non-metallic	25
Parts intended to be touched but not hand-held:	
Metallic	30
Non-metallic	40
Parts which need not be touched for normal operation:	
Metallic	40
Non-metallic	50
Parts not intended to be touched during normal operation	
Exteriors of enclosures adjacent to cable entries:	
Metallic	40
Non-metallic	50

[a] Different values may be prescribed for different test conditions and for devices of small dimensions but not exceeding by more than 10 K the values of this table.

8.2.2.4 Ambient air temperature

The temperature-rise limits given in Table 4 and Table 5 are applicable only if the ambient air temperature remains within the limits given in 7.1.1.

8.2.2.5 Main circuit

The main circuit of a contactor shall be capable of carrying without the temperature-rises exceeding the limits specified in 8.2.2.2 when tested in accordance with 9.3.3.3.4:

– for a contactor intended for continuous duty: its conventional thermal current (see 5.3.3.1 and/or 5.3.3.2);
– for a contactor intended for intermittent or temporary duty: the relevant rated operational current (see 5.3.3.3).

8.2.2.6 Control circuits

The control circuits of a contactor shall permit the rated duty according to 5.3.5 and also the temperature-rise tests specified in 9.3.3.3.5 to be made without the temperature-rise exceeding the limits specified in Table 3, Table 4 and Table 5.

8.2.2.7 Windings of coils and electromagnets

8.2.2.7.1 Eight-hour duty (continuous duty) windings

With the maximum value of current according to 8.2.2.5 flowing through the main circuit, the windings of the coils shall withstand under continuous load and at the rated frequency their rated control supply voltage without the temperature-rise exceeding the limits specified in Table 3 and 8.2.2.3.

8.2.2.7.2 Intermittent duty windings

With no current flowing through the main circuit, the windings of the coils shall withstand, at the rated frequency, their rated control supply voltage applied as detailed in Table 6, according to their intermittent duty class, without the temperature-rise exceeding the limits specified in Table 3 and 8.2.2.3.

Table 6 – Intermittent duty test cycle data

Intermittent duty classes	One close-open operating cycle every	Interval of time during which the supply to the control coil is maintained
1	3 600 s	"ON" time shall normally correspond to the on-load factor specified by the manufacturer
3	1 200 s	
12	300 s	
30	120 s	
300	12 s	
1 200	3 s	

8.2.2.7.3 Specially rated (short-time and periodic duty) windings

Specially rated windings shall be tested under operating conditions corresponding to the most severe duty for which they are intended and their ratings shall be stated by the manufacturer.

8.2.2.8 Auxiliary circuits

Auxiliary circuits of a contactor including auxiliary switches shall be capable of carrying their conventional thermal current without the temperature-rise exceeding the limits specified in Table 4 and Table 5 when tested in accordance with 9.3.3.3.7.

NOTE If an auxiliary circuit forms an integral part of the contactor, it suffices to test it at the same time as the main circuit, but at its actual service current.

8.2.2.9 Other parts

The temperature-rises obtained during the test shall not cause damage to current-carrying parts of adjacent parts of the contactor. In particular, for insulating materials, the manufacturer shall demonstrate compliance either by reference to the insulation temperature index (determined for example by the methods of IEC 60216) or by compliance with IEC 60085.

8.2.3 Dielectric properties

8.2.3.1 General

The dielectric properties are based on basic safety publications IEC 60664-1 and IEC 61140.

a) The following requirements provide the means of achieving co-ordination of insulation of a contactor with the conditions within the installation.

b) The contactor shall be capable of withstanding:

   – the rated impulse withstand voltage (see 5.3.2.3 in accordance with the over-voltage category given in Annex F;

   – the power-frequency withstand voltage.

   NOTE The correlation between the nominal voltage of the supply system and the rated impulse withstand voltage of the contactor is given in Annex F.

   The rated impulse withstand voltage for a given rated operational voltage shall be not less than that corresponding in Annex F to the nominal voltage of the supply system of the circuit at the point where the contactor is to be used, and the appropriate over-voltage category.

c) The requirements of this subclause shall be verified by the tests of 9.3.3.4.

8.2.3.2 Impulse withstand voltage

a) Main circuit

   1) Clearances from live parts to parts intended to be earthed and between poles shall withstand the test voltage given in Table 16 appropriate to the rated impulse withstand voltage.

   2) Solid insulation of contactor associated with clearances item a) 1) above shall be subjected to the impulse voltage specified in item a) 1).

b) Auxiliary and control circuits

   1) For auxiliary and control circuits which operate directly from the main circuit at the rated operational voltage, clearances from live parts to parts intended to be earthed and between poles shall withstand the test voltage given in Table 16 appropriate to the impulse withstand voltage of the main circuit. See also 8.2.3.2, item a) 2).

   2) Auxiliary and control circuits which do not operate directly from the main circuit may have an over-voltage withstand capacity different from that of the main circuit. Clearances and associated solid insulation of such circuits, whether a.c. or d.c., shall withstand the appropriate voltage in accordance with Annex F.

8.2.3.3 Power-frequency withstand voltage of the main, auxiliary and control circuits

a) Power-frequency dielectric tests are used in the following cases:

   – dielectric tests as type tests for the verification of solid insulation;

   – dielectric withstand verification, as a criterion of failure, after switching or short-circuit type tests;

   – routine tests.

b) Type tests of dielectric properties

   The tests of dielectric properties, as type tests, shall be made in accordance with 9.3.3.4.

c) Verification of dielectric withstand after switching or short-circuit tests

The verification of dielectric withstand after switching and short-circuit tests as a criterion of failure, is always made at power-frequency voltage in accordance with item d) of 9.3.3.4.1.

d) Verification of dielectric withstand during routine tests

Tests to detect faults in materials and workmanship are made at power-frequency voltage, in accordance with item b) of 9.3.3.4.2.

8.2.3.4 Clearances

Clearances shall be sufficient to enable the equipment to withstand the rated impulse withstand voltage, according to 8.2.3.2.

Clearances shall be higher than the values given in Table 17, for case B (homogeneous field) (see 3.5.30) and verified by a sampling test according to 9.3.3.4.3. This test is not required if the clearances, related to the rated impulse withstand voltage and pollution degree, are higher than the values given in Table 17 for case A (inhomogeneous field).

The method of measuring clearances is given in Annex E.

8.2.3.5 Creepage distances

a) Dimensioning

For pollution degrees 1 and 2, creepage distances shall be not less than the associated clearances selected according to 8.2.3.4. For pollution degree 3, the creepage distances shall be not less than the case A clearances (Table 17) to reduce the risk of disruptive discharge due to over-voltages, even if the clearances are smaller than the values of case A as permitted in 8.2.3.4.

The method of measuring creepage distances is given in Annex E.

Creepage distances shall correspond to a pollution degree as specified in 7.1.3.2 and to the corresponding material group at the rated insulation or working voltage given in Table 18.

Material groups are classified as follows, according to the range of values of the comparative tracking index (CTI) (see 3.5.33):

- Material group I 600 ≤ CTI
- Material group II 400 ≤ CTI < 600
- Material group IIIa 175 ≤ CTI < 400
- Material group IIIb 100 ≤ CTI < 175

NOTE The CTI values refer to the values obtained in accordance with IEC 60112, method A, for the insulating material used.

b) Use of ribs

A creepage distance can be reduced to 0,8 of the relevant value of Table 18 by using ribs of 2 mm minimum height, irrespective of the number of ribs. The minimum base of the rib is determined by mechanical requirements (see E.2).

8.2.3.6 Solid insulation

Solid insulation shall be verified by either power-frequency tests, in accordance with item c) of 9.3.3.4.1, or d.c. tests if a.c. tests cannot be applied.

Dimensioning rules for solid insulation and d.c. test voltages are under consideration.

8.2.3.7 Spacing between separate circuits

For dimensioning clearances, creepage distances and solid insulation between separate circuits, the highest voltage ratings shall be used (rated impulse withstand voltage for clearances and associated solid insulation and rated insulation voltage or working voltage for creepage distances).

8.2.3.8 Requirements for contactor with protective separation

Requirements for contactor with protective separation are given in Annex I.

8.2.4 Normal load and overload performance requirements

8.2.4.1 General

Requirements concerning normal load and overload characteristics according to 5.3.6 are given in 8.2.4.2, 8.2.4.3 and 8.2.4.4 below.

8.2.4.2 Making and breaking capacities

Contactors shall be capable of making and breaking currents without failure under the conditions stated in Table 7 for the required utilization categories and the number of operations indicated as specified in 9.3.3.5.

The values of off-time and on-time given in Table 7 and Table 8 shall not be exceeded.

Table 7 – Making and breaking capacities. Making and breaking conditions corresponding to the utilization categories

Categories	Making and breaking conditions					
	I_c/I_e	U_r/U_e	Cos φ	On-time [a] s	Off-time s	Number of operating cycles
AC-7a	1,5	1,05	0,80	0,05	[b]	50
AC-7b	8,0	1,05	0,45	0,05	[b]	50
AC-7c [c]	1,5	1,05	0,90	0,05	[b]	50

I_c is the current made and broken, expressed in r.m.s. symmetrical values, but it is understood that the actual peak value in the making operation may assume a higher value than the symmetrical peak value;

I_e is the rated operational current;

U_r is the power frequency recovery voltage;

U_e is the rated operational voltage;

Cos φ is the power factor of the test circuit.

[a] Time may be less than 0,05 s provided that contacts are allowed to become properly seated before re-opening.

[b] See Table 8.

[c] The test shall be done on a specific test circuit (see 9.3.3.5.2, item d) 2)).

Table 8 – Relationship between current broken I_c and off-time for the verification of rated making and breaking capacities

Current broken I_c A	Off-time s
$I_c \leq 100$	10
$100 < I_c \leq 200$	20
$200 < I_c \leq 300$	30

The values of off-time may be reduced if agreed by the manufacturer.

8.2.4.3 Conventional operational performance

Tests concerning the operational performance of a contactor are intended to verify that the contactor is capable of making, carrying and breaking without failure the currents flowing in its main circuit under conditions corresponding to the specified utilization category, where relevant.

Contactors shall be capable of making and breaking currents without failure under the conventional conditions stated in Table 9 for the required utilization categories and the number of operations indicated as specified in 9.3.3.6.

Table 9 – Conventional operational performance. Making and breaking conditions corresponding to the utilization categories

Categories	Making and breaking conditions					
	I_c/I_e	U_r/U_e	Cos φ	On-time [a] s	Off-time s	Number of operating cycles
AC-7a	1,0	1,05	0,80	0,05	[b]	30 000
AC-7b	[d]	[c]	0,45	0,05	[b]	30 000
AC-7c [e]	1,0	1,05	0,90	0,05	[b]	30 000

I_c is the current made and broken, expressed in r.m.s. symmetrical values, but it is understood that the actual peak value in the making operation may assume a higher value than the symmetrical peak value;

I_e is the rated operational current;

U_r is the power frequency recovery voltage;

U_e is the rated operational voltage;

Cos φ is the power factor of the test circuit.

[a] Time may be less than 0,05 s provided that contacts are allowed to become properly seated before re-opening.

[b] These OFF times shall be not greater than the values specified in Table 8.

[c] U_r/U_e = 1,0 for making and U_r/U_e = 0,17 for breaking.

[d] I_c/I_e = 6,0 for making and I_c/I_e = 1,0 for breaking.

[e] The test shall be done on a specific test circuit (see 9.3.3.5.2, item d) 2)).

8.2.4.4 Ability to withstand overload currents

Contactors with utilization category AC-7b shall withstand the overload currents given in Table 10 as specified in 9.3.5.

Table 10 – Overload current withstand requirements

Test current	Duration of test
$8 \times I_e$ max/AC-7b	10 s

8.2.5 Co-ordination with short-circuit protective devices

Performance under short-circuit conditions
(rated conditional short-circuit current)

The rated conditional short-circuit current of contactors backed up by short-circuit protective device(s) (SCPDs) shall be verified by short-circuit tests as specified in 9.3.4. These tests shall be made:

a) at the appropriate value of prospective current shown in Table 21 (test current I_r) and
b) at the rated conditional short-circuit current I_q, if higher than test current I_r.

The rating of the SCPD shall be adequate for any given rated operational current, rated operational voltage and the corresponding utilization category.

Test conditions are given in 9.3.4.3.

Co-ordination requires that, under short-circuit conditions, the contactor shall cause no danger to persons or installations. It is permissible that it is not suitable for further use.

NOTE Use of an SCPD not in compliance with the manufacturer's recommendations may invalidate the co-ordination.

8.3 Electromagnetic compatibility

8.3.1 Immunity

The behaviour of electromechanical contactors for household and similar purposes in case of voltage amplitude variations is specified in 8.2.1.2.

They are not sensitive to other electromagnetic disturbances in normal service conditions which occur in the environment described in 7.1.4. Therefore, no immunity tests are required.

8.3.2 Emission

Electromechanical contactors for household and similar purposes do not incorporate electronic circuits, or may incorporate only a simple rectifier circuit or components such as diodes, varistors, resistors or capacitors (for instance in the surge suppressors).

They can only generate electromagnetic disturbances during switching operations. The duration of the disturbances is of the order of milliseconds.

Provisionally, until further study is carried out, the frequency and the level of these emissions are considered as part of the normal electromagnetic environment of electromechanical contactors for household and similar purposes, and no electromagnetic emission tests are necessary.

9 Tests

9.1 Types of test

9.1.1 General

Tests shall be made to prove compliance with the requirements laid down in this standard. If relevant, tests may be carried out in sequences, see test sequences in Annex B.

9.1.2 Type tests

Type tests are intended to verify compliance of the contactor's design with this standard. They comprise the verification of:

a) temperature-rise limits (see 9.3.3.3);
b) dielectric properties (see 9.3.3.4);
c) rated making and breaking capacities (see 9.3.3.5);
d) conventional operational performance (see 9.3.3.6);
e) operation and operating limits (see 9.3.3.1 and 9.3.3.2);
f) overload current withstand capability (see 9.3.5);
g) performance under short-circuit conditions (see 9.3.4);
h) mechanical properties of terminals (see 9.2.5);
i) degrees of protection of enclosed contactors (see 9.2.4);
j) resistance to ageing (see 9.2.2.1);
k) resistance to humidity (see 9.2.2.2);
l) resistance to heat (see 9.2.2.3);
m) resistance to abnormal heat and fire (see 9.2.2.4);
n) resistance to rusting (see 9.2.2.5);
o) resistance to tracking (see 9.2.2.6);
p) screws or nuts other than those on terminals which are intended to be operated during installation or maintenance (see 9.2.3);
q) resistance to impact (see 9.2.6);
r) durability of marking (see 9.2.7).

If relevant, type tests are grouped in test sequences.

Test sequences, number of samples and results to be obtained are indicated in Annex B.

Unless otherwise specified, each test (or test sequence) is performed on a new sample in clean condition.

Unless otherwise specified, the contactors are tested at an ambient air temperature of 25 °C ± 10 °C.

9.1.3 Routine tests

Routine tests are intended to detect faults in materials and workmanship and to ascertain proper functioning of the contactor. They shall be made on each individual contactor under the same or equivalent conditions as those specified for type tests (see 9.3.6.1).

Routine tests for contactors comprise:

– operation and operating limits (see 9.3.6.2);

– dielectric tests (see 9.3.6.3).

9.1.4 Sampling tests for clearance verification

Sampling tests for clearance verification are made according to 9.3.3.4.3. Sampling plans and test procedures are under consideration.

9.2 Compliance with constructional requirements

9.2.1 General

Verification of compliance with the constructional requirements stated in 8.1 concerns, for example:

– the materials;
– the contactor;
– the degree of protection of enclosed contactors;
– the mechanical properties of terminals;
– the actuator;
– the position indicating device (see 3.3.16).

9.2.2 Materials

9.2.2.1 Test of resistance to ageing

Contactors incorporating separate gaskets, screwed glands, membranes and parts manufactured from rubber, p.v.c. or similar thermoplastic materials are subjected to a test in a heating cabinet with an atmosphere having the composition and pressure of the ambient air and ventilated by natural circulation, gaskets, glands and membranes being suspended freely.

The temperature in the cabinet is 70 °C ± 2 °C.

The samples shall be kept in the cabinet for seven days (168 h). The use of an electrically heated cabinet is recommended. Natural air circulation may be provided by holes in the walls of the cabinet.

After treatment, the samples shall be removed from the cabinet and kept at room temperature and relative humidity between 45 % and 55 % for at least four days (96 h).

The samples shall show, with normal or corrected vision without further magnification, neither surface crack nor shrinkage impairing their further use, nor shall the material have become sticky or greasy, this being judged as follows:

– with the forefinger wrapped in a dry piece of rough cloth the sample shall be pressed with a force of 5 N.

  The force of 5 N can be obtained in the following way:

– the sample is placed on one of the pans of a balance and the other pan is loaded with a mass equal to the mass of the sample plus 500 g. Equilibrium is then restored by pressing the sample with the forefinger wrapped in a dry piece of rough cloth.

No trace of the cloth shall remain on the sample and the material of the sample shall not stick to the cloth.

9.2.2.2 Test of resistance to humidity

The contactor resistance to humidity shall be verified by test Ca: damp heat, steady state of IEC 60068-2-78 under the following test conditions:

Inlet openings, if any, shall be left open; if knock-outs are provided, one of them shall be opened. Parts which can be removed without the aid of a tool shall be removed and subjected to the humidity treatment with the main parts: spring lids shall be open during this treatment.

Before being placed in the test chamber, the samples shall be stored at room temperature for at least 4 h before the test. The test duration shall be four days.

After this period, the contactor is removed from the test chamber, the removed parts are reinstalled and the lid closed. The contactor is then submitted to a dielectric test as specified in 9.3.3.4.1, item c).

9.2.2.3 Test of resistance to heat

9.2.2.3.1 Tests on contactor

a) Parts of insulating material, if any, necessary to retain in position current-carrying parts and parts of the earthing circuit shall be subjected to a ball pressure test at 125 °C ± 2 °C, except that insulating parts of an enclosure necessary to retain in position the earthing terminal, if any, shall be tested as specified in item b) hereafter.

   The ball-pressure apparatus is shown in Figure 3.

   The surface of the part to be tested shall be placed in a horizontal position and supported by a steel plate of at least 5 mm thickness and a steel ball of 5 mm diameter shall be pressed against this surface with a force of 20 N.

   The test shall be made in a heating cabinet at a temperature of 125 °C ± 2 °C.

   After 1 h, the ball shall be removed from the sample which shall then be cooled within 10 s to approximately room temperature by immersion in cold water.

   The diameter of the impression caused by the ball shall be measured and shall not exceed 2 mm.

   When it is not possible to make the test on the complete sample, the test shall be carried out on a suitable part of it of at least 2 mm thickness.

   NOTE The thickness of 2 mm can be obtained by using several layers.

b) External parts of insulating material not necessary to retain in position current-carrying parts and parts of the earthing circuit even though they may be in contact with them, shall be subjected to a ball-pressure test in accordance with item a) above, except that the test is made at a temperature of 70 °C ± 2 °C or 40 °C ± 2 °C plus the highest temperature-rise determined for the relevant part during the temperature-rise test, whichever is the higher.

c) Before being placed in the heating cabinet, the contactor under test shall be stored at room temperature for at least 4 h before the test.

   The contactor shall be kept for the time sufficient to reach thermal equilibrium, but not less than 1 hour in the heating cabinet at a temperature of 100 °C ± 2 °C.

   The sample shall then be allowed to cool to approximately room temperature.

   The standard test finger (see Figure 10) shall be applied to the external surfaces which are accessible during normal service with a force not exceeding 5 N, and there shall be no access to live parts when the contactor is mounted as in normal use. After the test, markings shall still be legible.

9.2.2.3.2 Tests on materials

A sample of the material, of at least 2 mm thickness, is subjected to the test(s) of 9.2.2.3.1, a) and/or b).

NOTE The manufacturer may provide data from the insulating material manufacturer (or other reliable source) to demonstrate compliance with these requirements.

9.2.2.4 Tests of resistance to abnormal heat and fire

9.2.2.4.1 Tests on parts of the contactor

The test to be performed for the verification of resistance to abnormal heat and fire is the glow-wire test, which simulates the thermal stresses produced by sources of heat or ignition in order to simulate fire hazard.

The glow-wire test shall be made according to IEC 60695-2-10 and IEC 60695-2-11 under the following conditions:

– for parts of insulating material, necessary to retain in position current-carrying parts by the test made at a temperature of 850 °C, for the purpose of this test a protective conductor, if any, is not considered as a current-carrying part,
– for parts of insulating material not necessary to retain in position current-carrying parts and parts of the earthing circuit, if any, even though they may be in contact with them, by the test made at a temperature of 650 °C.

9.2.2.4.2 Tests on materials

Suitable specimens of the material shall be subjected to the following tests:

NOTE The manufacturer may provide data from the insulating material manufacturer (or other reliable source) to demonstrate compliance with the requirements of 8.1.2.5.

a) Flammability classification test, in accordance with IEC 60695-11-10.
b) Hot wire ignition (HWI) test, as described in Annex G.

9.2.2.5 Test of resistance to rusting

All grease shall be removed from the parts to be tested, by immersion and agitation for 10 min in a cold chemical degreaser such as refined petrol.

The parts shall then be immersed for 10 min in a 10 % solution of ammonium chloride in water at a temperature of 20 °C ± 5 °C.

Without drying, but after shaking off any drops, the parts shall then be placed for 10 min in a box containing air saturated with moisture at a temperature of 20 °C ± 5 °C.

After the parts have been dried for 10 min in a heating cabinet at a temperature of 100 °C ± 5 °C, their surface shall show no signs of rust.

Traces of rust on sharp edges and any yellowish film removable by rubbing shall be ignored.

For small springs and the like, and for inaccessible parts exposed to abrasion, a layer of grease may provide sufficient protection against rusting.

Such parts shall only be subjected to the test if there is doubt about the effectiveness of the grease film, the test shall then be made without previous removal of the grease.

NOTE A revision of this test is under consideration.

9.2.2.6 Test of resistance to tracking

This test shall be made on a suitable part taken from the contactor or, if agreed for practical reasons, on a suitable specimen of the insulating material, according to IEC 60112, Solution A.

9.2.3 Test on screws or nuts other than those on terminals which are intended to be operated during installation or maintenance

The screws or nuts shall be tightened and loosened:

– 10 times when in engagement with a thread of insulating material,
– 5 times in all other cases.

Screws or nuts in engagement with a thread of insulating material shall be completely removed and reinserted each time.

The test shall be made with a suitable screwdriver or spanner, applying a torque as given in Table 11 or as specified by the manufacturer.

The screws or nuts shall be tightened without jerks.

When a screw has a hexagonal head with a slot for tightening with a screwdriver and when Table 11 is used and the values in columns II and III are different, the test shall be made twice:

– first applying to the hexagonal head the torque specified in column III by means of the spanner,
– then, on a new sample, applying the torque specified in column II by means of the screwdriver.

If the values in columns II and III are the same, only the test with the screwdriver shall be made.

During the test, the screwed connections shall not work loose and there shall be no damage, such as breakage of screws or damage to the head slots, threads, washers or stirrups, or damage to enclosures and covers, that will impair the further use of the contactor.

9.2.4 Verification of the degrees of protection of enclosed contactors

See Annex H.

9.2.5 Mechanical properties of terminals

This subclause does not apply to aluminium terminals or to terminals for the connection of aluminium conductors.

9.2.5.1 General conditions for tests

Unless otherwise stated by the manufacturer, each test shall be made on terminals in a clean and new condition.

When tests are made with round copper conductors, the copper shall be according to IEC 60028.

9.2.5.2 Tests of mechanical strength of terminals

Tests shall be made with the appropriate type of conductor having the maximum cross-sectional area.

The conductor shall be connected and disconnected five times.

For screw-type terminals, the tightening torque shall be in accordance with Table 11 or 110 % of the torque specified by the manufacturer, whichever is the greater.

The test shall be conducted on two separate clamping units.

When a screw has a hexagonal head with means for tightening with a screwdriver and the values in columns II and III are different, the test is made twice, first applying to the hexagonal head the torque specified in column III, and then, on another set of samples, applying the torque specified in column II by means of a screwdriver.

If the values in columns II and III are the same, only the test with the screwdriver is made.

Each time the clamping screw or nut is loosened, a new conductor shall be used for each tightening test.

During the test, clamping units and terminals shall not work loose and there shall be no damage, such as breakage of screws or damage to the head slots, threads, washers or stirrups that will impair the further use of the screwed connections.

Table 11 – Tightening torques for the verification of the mechanical strength of screw-type terminals

Diameter of thread mm		Tightening torque N.m		
Metric standard values	**Range of diameter**	**I**	**II**	**III**
2,5	≤2,8	0,2	0,4	0,4
3,0	>2,8 up to and including 3,0	0,25	0,5	0,5
–	>3,0 up to and including 3,2	0,3	0,6	0,6
3,5	>3,2 up to and including 3,6	0,4	0,8	0,8
4	>3,6 up to and including 4,1	0,7	1,2	1,2
4,5	>4,1 up to and including 4,7	0,8	1,8	1,8
5	>4,7 up to and including 5,3	0,8	2,0	2,0
6	>5,3 up to and including 6,0	1,2	2,5	3,0
8	>6,0 up to and including 8,0	2,5	3,5	6,0
10	>8,0 up to and including 10,0	–	4,0	10,0
Column I	applies to screws without heads which, when tightened, do not protrude from the hole, and to other screws which cannot be tightened by means of a screwdriver with a blade wider than the root diameter of the screw.			
Column II	applies to nuts and screws which are tightened by means of a screwdriver.			
Column III	applies to nuts and screws which can be tightened by means other than a screwdriver.			

9.2.5.3 Tests for damage to and accidental loosening of conductors (flexion test)

The test applies to terminals for the connection of unprepared round copper conductors, of number, cross-section and type (flexible and/or rigid [stranded and/or solid]), specified by the manufacturer.

The following tests shall be carried out using two new samples with:

a) the maximum number of conductors of the smallest cross-section connected to the terminal;
b) the maximum number of conductors of the largest cross-section connected to the terminal;
c) the maximum number of conductors of the smallest and largest cross-sections connected to the terminal.

Terminals intended for connection of either flexible or rigid (solid and/or stranded) conductors shall be tested with each type of conductor with different sets of samples.

Terminals intended for connection of both flexible and rigid (solid and/or stranded) conductors simultaneously shall be tested as stated in c) above.

The test should be carried out with suitable test equipment. The specified number of conductors shall be connected to the terminal. The length of the test conductors should be 75 mm longer than the height *H* specified in Table 12. The clamping screws shall be tightened with a torque in accordance with Table 11 or with the torque specified by the manufacturer. The device tested shall be secured as shown in Figure 4.

Table 12 – Test values for flexion and pull-out tests for round copper conductors

Conductor cross-section		**Diameter of bushing hole** [a]	**Height** ***H*** **± 13 mm**	**Mass**	**Pulling force**
mm^2	AWG/MCM	mm	mm	kg	N
0,2	24	6,4	260	0,3	10
–	22	6,4	260	0,3	20
0,5	20	6,4	260	0,3	30
0,75	18	6,4	260	0,4	30
1,0	–	6,4	260	0,4	35
1,5	16	6,4	260	0,4	40
2,5	14	9,5	279	0,7	50
4,0	12	9,5	279	0,9	60
6,0	10	9,5	279	1,4	80
10	8	9,5	279	2,0	90
16	4	12,7	298	2,9	100
25	6	12,7	298	4,5	135
–	3	14,3	318	5,9	156
35	2	14,3	318	6,8	190

[a] If a bushing with the hole diameter given is not adequate to accommodate the conductor without binding, a bushing having the next larger hole may be used.

Each conductor is subjected to circular motions according to the following procedure:

The end of the conductor under test shall be passed through an appropriate size bushing in a platen positioned at a height *H* below the contactor terminal, as given in Table 12. The other conductors shall be bent in order not to influence the result of the test. The bushing shall be positioned in the horizontal platen concentric with the conductor. The bushing shall be moved so that its centre-line describes a circle of 75 mm diameter about its centre in the horizontal plane at 10 r.p.m. ± 2 r.p.m. The distance between the mouth of the terminal and the upper surface of the bushing shall be within 13 mm of the height *H* in Table 12. The bushing is to be lubricated to prevent binding, twisting or rotation of the insulated conductor. A mass as specified in Table 12 is to be suspended from the end of the conductor. The test shall consist of 135 continuous revolutions.

During the test, the conductor shall neither slip out of the terminal nor break near the clamping unit.

Immediately after the flexion test, each conductor under test shall be submitted in the test equipment to the test of 9.2.5.4 (pull-out test).

9.2.5.4 Pull-out test for round copper conductors

Following the test of 9.2.5.3, the pulling force given in Table 12 shall be applied to the conductor tested in accordance with 9.2.5.3.

The clamping screws shall not be tightened again for this test.

The force shall be applied without jerks for one minute.

During the test, the conductor shall neither slip out of the terminal nor break near the clamping unit.

9.2.5.5 Test for insertability of unprepared round copper conductors having the maximum specified cross-section

9.2.5.5.1 Test procedure

The test shall be carried out with the gauges specified in Table 13. The measuring section of the gauge shall be able to penetrate into the terminal aperture under the weight of the gauge to the full depth of the terminal (see also Note to Table 13).

Table 13 – Maximum conductor cross-sections and corresponding gauges

Conductor cross-sections		**Gauges** (see Figure 5)			
Flexible conductors mm²	**Rigid conductors (solid or stranded)** mm²	**Form and marking**	**Diameter *a*** mm	**Width *b*** mm	**Permissible deviations for *a* and *b*** mm
1,5	1,5	A1	2,4	1,5	0 –0,05
2,5	2,5	A2	2,8	2,0	
2,5	4	A3	2,8	2,4	
4	6	A4	3,6	3,1	0 –0,06
6	10	A5	4,3	4,0	
10	16	B6	5,3	–	
16	25	B7	6,9	–	0 –0,07
25	35	B8	8,7	–	
35	50	B9	10,0	–	
NOTE For conductor cross-sections other than those given in the table, an unprepared conductor of appropriate cross-section may be used as the gauge, the force of insertion being not greater than 5 N.					

9.2.5.5.2 Construction of gauges

The construction of the gauges is shown in Figure 5.

Details of dimensions *a* and *b* and their permissible deviations are shown in Table 13. The measuring section of the gauge shall be made from gauge steel.

9.2.6 Test of resistance to impact

9.2.6.1 Test procedure

Unenclosed contactors, exposed parts of partially enclosed contactors, covers and cover plates of contactors shall be tested with the pendulum hammer test apparatus (see 9.2.6.2.1) with a shock energy of 0,5 J.

Enclosures designed and dimensioned to contain a contactor shall be tested with the sphere test apparatus (see 9.2.6.2.2) with a shock energy of 2 J.

The ambient air temperature shall be 25 °C ± 10 °C.

The sample with cover, or the enclosure, if any, shall be fixed as in normal use or placed against a rigid support.

Cable entries which are not provided with knock-outs shall be left open. If they are provided with knock-outs, two of them shall be opened.

Before applying the blows, fixing screws of bases, covers and the like shall be tightened with a torque equal to two thirds of that specified in Table 11.

The samples are subjected to ten blows, which are evenly distributed over the sample. The blows are not applied to knock-outs, fragile parts such as windows, pilot lights, etc.

In general, five of the blows are applied as follows:

– for flush-type contactors, one blow in the centre, one at each extremity of the area over the recess in the block, and the other two approximatively midway between the previous blows, preferably on the ridge, if any, the sample being moved horizontally;
– for other contactors and for mounting boxes, one blow in the centre, one at each side of the sample after it has been turned as far as possible, but not through more than 60°, about a vertical axis, and the other two approximatively midway between the previous blows, preferably on the ridge, if any.

The remaining blows are then applied in the same way, after the sample has been turned through 90° about its axis perpendicular to the plywood.

After the test, the sample shall show no damage within the meaning of this standard.

In particular, covers which when broken make live parts accessible or impair the further use of the contactor, operating means, and linings and barriers of insulating materials and the like, shall not show such damage.

In case of doubt, it is verified that removal and replacement of external parts, such as enclosures and covers, is possible without these parts or their lining being damaged.

Damage to the appearance, for example surface cracks, small dents which do not reduce the clearances or creepage distances below the values specified in 8.2.3.4 and 8.2.3.5, and small chips which do not adversely affect the protection against electric shock shall be neglected.

9.2.6.2 Test apparatus

9.2.6.2.1 Pendulum hammer test apparatus (0,5 J test)

The test apparatus shown in Figure 6, Figure 7 and Figure 8 shall be used.

The design of the test apparatus shall be such that:

– the sample can be moved horizontally and turned about an axis perpendicular to the surface of the plywood;
– the plywood can be turned about a vertical axis.

The striking element, having a mass of 0,25 kg, shall be allowed to fall from a height of 0,20 m on to surfaces which are exposed when the contactor is mounted as in normal conditions of use so that the point of impact lies in the vertical plane through the axis of the pivot of the pendulum.

The height of fall shall be the vertical distance between the position of a checking point when the pendulum is released and the position of that point at the moment of impact. The checking point shall be marked on the surface of the striking element where the line through the point of intersection of the axis of the steel tube of the pendulum and that of the striking element, and perpendicular to the plane through both axes, meets the surface.

The head of the striking element shall have a hemispherical face of radius 10 mm and shall be of polyamide having a Rockwell hardness of R 100. The striking element is rigidly fixed to the lower end of a steel tube with an external diameter of 9 mm and a wall thickness of 0,5 mm, which shall be pivoted at its upper end in such a way that it swings only in a vertical plane.

The axis of the pivot shall be 1 000 mm ± 1 mm, above the axis of the striking element.

For determining the Rockwell hardness of the polyamide of the head of the striking element, the following conditions shall apply:

– diameter of the ball: 12,7 mm ± 0,002 5 mm,
– initial load: 100 N ± 2 N,
– overload: 500 N ± 2,5 N.

Additional information concerning the determination of the Rockwell hardness of plastics is given in ISO 2039-2. Surface-mounting contactors shall be mounted on a sheet of plywood, 8 mm thick and 175 mm square, secured at its top and bottom edges to a rigid bracket, which shall be part of the mounting support as shown in Figure 7.

The mounting support shall have a mass of 10 kg ± 1 kg and shall be mounted on a rigid frame by means of pivots.

9.2.6.2.2 Sphere test apparatus (2 J test) (see Figure 9)

The impact shall be produced by dropping or swinging a steel sphere 50 mm in diameter and weighing 0,5 kg from a height of 0,4 m as shown in Figure 9.

H indicates the vertical distance the sphere must travel to produce the desired impact. The sphere is to contact the test sample when the wire is in the vertical position.

The wire shall have a negligible mass in comparison with the sphere.

The supporting surface shall consist of a layer of tongue-and-groove oak flooring mounted on two layers of 19 mm plywood.

The oak flooring shall be nominally 19 mm thick. The assembly shall rest on a concrete floor. An equivalent non-resilient supporting surface may be used.

The backing support shall consist of 19 mm plywood over a rigid surface of concrete.

An equivalent non-resilient backing support may be used.

9.2.7 Test of durability of marking

Compliance with the requirements of 8.1.13 is checked by inspection, also by lightly rubbing the marking by hand for 15 s with a piece of cloth soaked with water and again for 15 s with a piece of cloth soaked with petroleum spirit.

Petroleum spirit used in the test should consist of aliphatic solvent hexane with a content of aromatics of maximum 0,1 % by volume, a kAuributanol value of 29, an initial boiling point of approximately 65 °C, a dry-point of approximately 69 °C and a density of approximately 0,68 g/cm^3.

After this test the marking shall be easily legible. It shall not be easily possible to remove labels and these shall show no curling.

The marking shall also remain easily legible after all the tests of this standard.

Marking made by impression, moulding, pressing or engraving is not subjected to this test.

9.3 Compliance with performance requirements

9.3.1 Test sequences

The sequence of tests and the corresponding samples are indicated in Annex B.

9.3.2 General test conditions

9.3.2.1 General requirements

The contactors to be tested shall agree in all their essential details with the design of the type which they represent.

Unless otherwise stated in the relevant test clauses, the tests shall be made with the same kind of current (and, at the rated frequency and with the same number of phases) as in the intended service.

If, for convenience of testing, it appears desirable to increase the severity of a test (e.g. to adopt a higher rate of operation in order to reduce the duration of the test), this may be done only with the consent of the manufacturer.

The contactor under test shall be mounted complete on its own support or an equivalent support and connected as in normal service, in accordance with the manufacturer's instructions and under the ambient conditions stated in 7.1.

Enclosed contactors shall be mounted complete and any opening normally closed in service shall be closed for tests. Contactors intended for use in an individual enclosure shall be tested in the smallest of such enclosures stated by the manufacturer.

NOTE An individual enclosure is an enclosure designed and dimensioned to contain one contactor only.

Contactors not intended to be used in an individual enclosure shall be tested in free air. In this case, unless otherwise specified in the relevant test clauses of this standard, for tests concerning making and breaking capacities and performance under short-circuit conditions, a wire mesh shall be placed at all points of the contactor likely to be a source of external phenomena capable of producing a breakdown, in accordance with the arrangements and distances specified by the manufacturer. Details, including distances from the contactor under test to the wire-mesh, shall be stated in the test report.

Maintenance or replacement of parts is not permitted, unless otherwise specified in this standard.

The contactor may be operated without load prior to beginning a test.

For the tests, the actuating system, if any, shall be operated as for the intended use in service stated by the manufacturer and at the rated values of control quantities (such as voltage), unless otherwise specified in this standard.

9.3.2.2 Test quantities

9.3.2.2.1 Values of test quantities

All the tests shall be made with the values of test quantities corresponding to the ratings assigned by the manufacturer, in accordance with the relevant tables and data of this standard.

9.3.2.2.2 Tolerances on test quantities

The test recorded in the test report shall be within the tolerances given in Table 14, unless otherwise specified in the relevant subclauses. However, with the agreement of the manufacturer, the tests may be made under more severe conditions than those specified.

Table 14 – Tolerances on test quantities

All tests	Tests under no load, normal load and overload conditions	Tests under short-circuit conditions
– current: $^{+5}_{0}$ %	– power factor: ±0,5	– power factor: $^{0}_{-0,05}$
– voltage: $^{+5}_{0}$ %		
(including power frequency recovery voltage)	– frequency: ±5 %	– frequency: ±5 %
NOTE 1 Where maximum and/or minimum operating limits are stated in this standard, the above tolerances do not apply. NOTE 2 By agreement between manufacturer and user, tests made at 50 Hz may be accepted for operation at 60 Hz and vice-versa.		

9.3.2.2.3 Recovery voltage

a) *Power-frequency recovery voltage*

For all breaking capacity and short-circuit breaking capacity tests, the value of the power-frequency recovery voltage shall be 1,05 times the value of the rated operational voltage.

NOTE 1 The value of 1,05 times the rated operational voltage for the power-frequency recovery voltage is deemed to cover the effects of the variations of the system voltage under normal service conditions.

NOTE 2 This may require that the applied voltage be increased but the prospective peak-making current should not be exceeded without the consent of the manufacturer.

NOTE 3 The upper limit of the power-frequency recovery voltage may be increased with the approval of the manufacturer (see 9.3.2.2.2).

b) *Transient recovery voltage*

Transient recovery voltages, where required in this standard, are determined according to 9.3.3.5.3.

9.3.2.3 Evaluation of test results

The behaviour of the contactor during the tests and its condition after the tests are specified in the relevant test clauses of this standard.

9.3.2.4 Test reports

Written reports on type tests proving compliance with this standard shall be made available by the manufacturer. The details of test arrangements such as type and size of the enclosure, if any, size of conductors, distance from the live parts to the enclosure or to parts normally earthed in service, method of operation of the actuating system, etc., shall be given in the test report.

Test values and parameters shall form part of the test report.

9.3.3 Performance under no load, normal load and overload conditions

9.3.3.1 Operation

It shall be verified that contactors operate according to the requirements of 8.2.1.1.

9.3.3.2 Operating limits

Contactors shall be tested to verify the performance according to the requirements given in 8.2.1.2.

9.3.3.3 Temperature-rise

9.3.3.3.1 Ambient air temperature

The ambient air temperature shall be recorded during the last quarter of the test period by at least two temperature sensing means, e.g. thermometers or thermocouples, equally distributed around the contactor at about half its height and at a distance of about 1 m from the contactor. The temperature sensing means shall be protected against air currents, heat radiation and indicating errors due to rapid temperature changes.

During the tests, the ambient air temperature shall be between +10 °C and +40 °C and not vary by more than 10 K.

9.3.3.3.2 Measurement of the temperature of parts

For parts other than coils, the temperature of the different parts shall be measured by suitable temperature sensing means at those points most likely to attain the maximum temperature; these points shall be stated in the test report.

The temperature sensing means shall not significantly affect the temperature-rise.

Good thermal conductivity between the temperature sensing means and the surface of the part under test shall be ensured.

For electromagnet coils, the method of measuring the temperature by variation of resistance shall generally be used. Other methods are permitted only if it is impracticable to use the resistance method.

The temperature of the coils before beginning the test shall not differ from that of the surrounding medium by more than 3 K.

For copper conductors, the value of the hot temperature T_2 may be obtained from the value of the cold temperature T_1 as a function of the ratio of the hot resistance R_2 to the cold resistance R_1 by the following formula:

$$T_2 = \frac{R_2}{R_1} \quad (T_1 + 234,5) - 234,5$$

where

T_1 and T_2 are expressed in degrees Celsius.

The test shall be made for a time sufficient for the temperature-rise to reach a steady-state value, but not exceeding 8 h. It is assumed that a steady-state is reached when the variation does not exceed 1 K per hour.

9.3.3.3.3 Temperature-rise of a part

The temperature-rise of a part is the difference between the temperature of that part measured in accordance with 9.3.3.3.2 and the ambient air temperature measured in accordance with 9.3.3.3.1.

9.3.3.3.4 Temperature-rise of the main circuit

The contactor shall be mounted as specified in 9.3.2.1 and shall be protected against abnormal external heating or cooling.

The main circuit shall be loaded as stated in 8.2.2.5.

All auxiliary circuits which normally carry current shall be loaded at their maximum rated operational current (see 5.6) and the control circuits shall be energized at their rated voltage.

Contactors having an integral enclosure and contactors only intended for use with a specified type of enclosure shall be tested in their enclosure for the conventional thermal current test. No opening giving false ventilation shall be allowed.

Contactors intended for use with more than one type of enclosure shall be tested either in the smallest enclosure stated by the manufacturer to be suitable or tested without an enclosure. If tested without an enclosure the manufacturer shall be prepared to state a value of conventional enclosed thermal current (see 5.3.3.2).

For tests with multiphase currents, the current shall be balanced in each phase within ±5 %, and the average of these currents shall be not less than the appropriate test current.

Unless otherwise specified in this standard, the temperature-rise test of the main circuit is made at one or both of the conventional thermal currents, as defined in 5.3.3.1 and 5.3.3.2 and may be made at any convenient voltage.

When the heat exchange between the main circuit, the control circuit and the auxiliary circuits may be of significance, the temperature-rise tests stated in 9.3.3.3.4, 9.3.3.3.5, 9.3.3.3.6 and 9.3.3.3.7 shall be made simultaneously.

In the case of multipole contactors, the test may be carried out but, subject to the manufacturer's agreement, with single-phase current with all poles connected in series.

At the end of the test, the temperature-rise of the different parts of the main circuit shall not exceed the values given in Table 4 and Table 5.

The following test connection arrangements shall be used:

a) The connections shall be single-core, p.v.c.-insulated, copper conductors with cross-sections as given in Table 15.
b) The connections shall be in free air, and spaced at approximately the distance existing between the terminals.
c) For single-phase or multi-phase tests, the minimum length of any temporary connection from a terminal to another terminal or to the test supply or to a star point shall be 1 m.

Table 15 – Test copper conductors

Range of test current [a]		Conductor size [b, c]	
A		mm²	AWG/MCM
0	8	1,0	18
8	12	1,5	16
12	15	2,5	14
15	20	2,5	12
20	25	4,0	10
25	32	6,0	10
32	50	10	8
50	65	16	6
65	85	25	4

[a] The value of the test current shall be greater than the first value in the first column and less than or equal to the second value in that column.

[b] For convenience of testing and with the manufacturer's consent, smaller conductors than those given for a stated test current may be used.

[c] The table gives alternative sizes for conductors in the metric and AWG/MCM systems.

9.3.3.3.5 Temperature-rise of control circuits

The temperature-rise of control circuits shall be measured during the test of 9.3.3.3.4.

The temperature-rise tests of control circuits shall be made with the specified current and at the rated frequency. Control circuits shall be tested at their rated voltage.

Circuits intended for continuous operation shall be tested for a sufficient time for the temperature-rise to reach a steady-state value.

At the end of these tests the temperature-rise of the different parts of the control circuits shall not exceed the values specified in 8.2.2.6.

9.3.3.3.6 Temperature-rise of coils of electromagnets

Coils and electromagnets shall be tested according to the conditions given in 8.2.2.7.

They shall be tested for a sufficient time for the temperature-rise to reach a steady-state value.

The temperature shall be measured when thermal equilibrium is reached in both the main circuit and the coil of the electromagnet.

Coils and electromagnets of contactors shall be tested as follows:

a) Electromagnets of contactors intended for a duty period of 8 h (continuous duty) shall be subjected only to the test prescribed in 8.2.2.7.1, with the corresponding rated current flowing through the main circuit for the duration of the test. The temperature-rise shall be measured during the test of 9.3.3.3.4.
b) Electromagnets of contactors intended for intermittent duty shall be subjected to the test as stated above, and also to the test prescribed in 8.2.2.7.2 dealing with their duty class, with no current flowing through the main circuit.
c) Specially rated (short-time and periodic duty) windings shall be tested as stated in 8.2.2.7.3 without current in the main circuit.

At the end of these tests the temperature-rise of the different parts shall not exceed the values specified in 8.2.2.7.

9.3.3.3.7 Temperature-rise of auxiliary circuits

The temperature-rise tests of auxiliary circuits shall be made during the test of 9.3.3.3.4 under the same conditions as those specified in 9.3.3.3.5, but may be carried out at any convenient voltage.

At the end of these tests the temperature-rise of the auxiliary circuits shall not exceed the values specified in 8.2.2.8.

9.3.3.4 Dielectric properties

9.3.3.4.1 Type tests

a) General conditions for withstand voltage tests

   The contactor to be tested shall comply with the general requirements of 9.3.2.1.

   If the contactor is to be used without an enclosure, it shall be mounted on a metal plate and all exposed conductive parts (frame, etc.) intended to be connected to the protective earth in normal service shall be connected to that plate.

   When the base of the contactor is of insulating material, metallic parts shall be placed at all of the fixing points in accordance with the conditions of normal installation of the contactor and these parts shall be considered as part of the frame of the contactor.

   Any actuator of insulating material and any integral non-metallic enclosure of contactor intended to be used without an additional enclosure shall be covered by a metal foil and connected to the frame or the mounting plate. The foil shall only be applied to those parts of surface which can be touched with the standard test finger (see Figure 10) during operation or adjustment of the contactor. If the insulation part of an integral enclosure cannot be touched by the standard test finger due to the presence of an additional enclosure, no foil shall be required.

b) Verification of impulse withstand voltage

   1) General

      The contactor shall comply with the requirements stated in 8.2.3.2.

      The verification of the insulation is made by a test at the rated impulse withstand voltage.

      Clearances equal to or larger than the values of class A of Table 17 may be verified by measurement, according to the method described in Annex E.

   2) Test voltage

      The test voltage shall be that specified in 8.2.3.2.

      For contactor incorporating over-voltage suppressing means, the energy content of the test current shall not exceed the energy rating of the over-voltage suppressing means. The latter shall be suitable for the application.

      NOTE 1 Such ratings are under consideration.

      The test equipment shall be calibrated to produce a 1,2/50 μs waveform as defined in IEC 61180. The output is then connected to the contactor to be tested and the impulse applied five times for each polarity at intervals of 1 s minimum. The influence of the contactor under test on the waveshape, if any, is ignored.

   3) Application of test voltage

      With the contactor mounted and prepared as specified in item 1) above, the test voltage is applied as follows:

      i) between all the terminals of the main circuit connected together (including the control and auxiliary circuits connected to the main circuit) and the enclosure or mounting plate, with the contacts in all normal positions of operation;

ii) between each pole of the main circuit and the other poles connected together and to the enclosure or mounting plate, with the contacts in all normal positions of operation;

iii) between each control and auxiliary circuit not normally connected to the main circuit and:

- the main circuit,
- the other circuits,
- the exposed conductive parts,
- the enclosure or mounting plate,

which, wherever appropriate, may be connected together;

4) Acceptance criteria

There shall be no unintentional disruptive discharge during the tests.

NOTE 2 An exception is an intentional disruptive discharge, for example by transient over-voltage suppressing means.

NOTE 3 The term "disruptive discharge" related to phenomena associated with the failure of insulation under electrical stress, in which the discharge completely bridges the insulation under test, reducing the voltage between the electrodes to zero or nearly to zero.

NOTE 4 The term "sparkover" is used when a disruptive discharge occurs in a gaseous or liquid dielectric.

NOTE 5 The term "flashover" is used when a disruptive discharge occurs over the surface of a dielectric in a gaseous or liquid medium.

NOTE 6 The term "puncture" is used when a disruptive discharge occurs through a solid dielectric.

NOTE 7 A disruptive discharge in a solid dielectric produces permanent loss of dielectric strength; in a liquid or gaseous dielectric, the loss may be only temporary.

c) Power-frequency withstand verification of solid insulation

1) General

This test applies to the verification of solid insulation and the ability to withstand temporary over-voltages.

The values of Table 19 are deemed to cover the ability to withstand temporary over-voltages (see Footnote a of Table 19).

2) Test voltage

The test voltage shall have a practically sinusoidal waveform and a frequency between 45 Hz and 65 Hz. The high-voltage transformer used for the test shall be so designed that, when the output terminals are short-circuited after the output voltage has been adjusted to the appropriate test voltage, the output current shall be at least 200 mA.

The over-current relay shall not trip when the output current is less than 100 mA.

The value of the test voltage shall be as follows:

i) for the main circuit, and for the control and auxiliary circuits, in accordance with Table 19. The uncertainty of measurement of the test voltage shall not exceed ±3 %.

ii) if an alternating test voltage cannot be applied, for example due to EMC filter components, a direct test voltage may be used having the value of Table 19, third column. The uncertainty of measurement of the test voltage shall not exceed ±3 %.

The test voltage applied shall be within ±3 %.

3) Application of test voltage

For the dielectric test between phases, all circuits between these phases may be disconnected for the test.

NOTE 8 The purpose of this test is to check the basic and supplementary insulation only.

For the dielectric test between phase and earth, all circuits shall be connected.

NOTE 9 The purpose of this test is to check both basic and supplementary insulation, and the ability to withstand temporary over-voltages.

The test voltage shall be applied to for 5 s in accordance with items b) 3) i), b) 3) ii) and b) 3) iii) above.

4) Acceptance criteria

During the test, no flashover, breakdown of insulation either internally (puncture) or externally (tracking) or any other manifestation of disruptive discharge shall occur. Any glow discharge shall be ignored. Components connected between phase and earth may be damaged during the tests but such failure shall not result in a condition that would lead to a hazardous situation.

NOTE 10 The voltage levels to earth are based on IEC 60664-1 under worst case conditions which generally do not occur in practice.

d) Power-frequency withstand verification after switching tests

1) General

The test should be performed on the contactor whilst it remains mounted for the switching tests. If this is not practicable, it may be disconnected and removed from the test circuit, although measures shall be taken to ensure that this does not influence the result of the test.

2) Test voltage

The requirements of item c) 2) above shall apply except that the value of the test voltage shall be 2 U_e with a minimum of 1 000 V r.m.s. or 1 415 V d.c. if an a.c. voltage test cannot be applied. The value of U_e referred to is that at which switching tests have been performed.

3) Application of test voltage

The requirements of item c) 3) above shall apply. The application of the metal foil, according to 9.3.3.4.1, item a), is not required.

4) Acceptance criteria

The requirements of item c) 4) above shall apply.

e) Verification of d.c. withstand voltage

Under consideration.

f) Verification of creepage distances

The shortest creepage distances between phases, between circuit conductors at different voltages and live and exposed conductive parts shall be measured. The measured creepage distance with respect to material group and pollution degree shall comply with the requirements of 8.2.3.5.

9.3.3.4.2 Routine tests

a) Impulse withstand voltage

The tests shall be performed in accordance with item b) of 9.3.3.4.1. The test voltage shall be not less than 30 % of the rated impulse withstand voltage (without altitude correction factor) or 2 U_i whichever is the higher.

b) Power-frequency withstand voltage

1) Test voltage

The test apparatus shall be the same as that stated in item c) 2) of 9.3.3.4.1 except that the over-current trip should be set at 25 mA.

However, at the discretion of the manufacturer for safety reasons, test apparatus of a lower power or trip setting may be used, but the short-circuit current of the test apparatus shall be at least eight times the nominal trip setting of the over-current relay, for example for a transformer with a short-circuit current of 40 mA, the maximum trip setting of the over-current relay shall be 5 mA ± 1 mA.

NOTE 1 The capacitance of the contactor may be taken into account.

The r.m.s. value of the test voltage shall be 2 U_e with a minimum of 1 000 V r.m.s.

NOTE 2 In the case of multiple values, U_e refers to the highest value marked on the contactor or given in the manufacturer's documentation.

2) Application of test voltage

The requirements of item c) 3) of 9.3.3.4.1 shall apply, except that the duration of the test voltage shall be 1 s only.

However, as an alternative, a simplified test procedure may be used if it is considered to subject the insulation to an equivalent dielectric stress.

3) Acceptance criteria

The over-current relay shall not trip.

c) Combined impulse voltage and power-frequency withstand voltage

The tests of items a) and b) above may be replaced by a single power-frequency withstand test where the peak value of the sinusoidal wave corresponds to the value stated in items a) or b), whichever is the higher.

d) In no case the application of the metal foil according to 9.3.3.4.1, item a) is required.

9.3.3.4.3 Sampling tests for verification of clearances

a) General

These tests are intended to verify the maintaining of the design conformity regarding clearances and are only applicable to contactor with clearances smaller than those corresponding to Table 17, case A.

b) Test voltage

The test voltage shall be that corresponding to the rated impulse withstand voltage.

c) Application of test voltage

The requirements of item b) 3) of 9.3.3.4.1 shall apply, except that the metal foil need not be applied to the actuator or the enclosure.

d) Acceptance criteria

No disruptive discharge shall occur.

9.3.3.4.4 Tests for contactor with protective separation

Tests for contactor with protective separation are given in Annex I.

Table 16 – Impulse test voltages and corresponding altitudes

Rated impulse withstand voltage U_{imp} kV	$U_{1,2/50}$, impulse kV				
	Sea level	200 m	500 m	1 000 m	2 000 m
0,33	0,36	0,36	0,35	0,34	0,33
0,5	0,54	0,54	0,53	0,52	0,5
0,8	0,95	0,9	0,9	0,85	0,8
1,5	1,8	1,7	1,7	1,6	1,5
2,5	2,9	2,8	2,8	2,7	2,5
4	4,9	4,8	4,7	4,4	4
6	7,4	7,2	7	6,7	6
8	9,8	9,6	9,3	9	8

Table 17 – Minimum clearances in air

Rated impulse withstand voltage U_{imp} kV	Minimum clearances mm							
	Case A Inhomogeneous-field conditions (see 3.5.31)				Case B Homogeneous-field ideal conditions (see 3.5.30)			
	Pollution degree				Pollution degree			
	1	2	3	4	1	2	3	4
0,33	0,01				0,01			
0,5	0,04	0,2			0,04	0,2		
0,8	0,1		0,8		0,1		0,8	1,6
1,5	0,5	0,5		1,6	0,3	0,3		
2,5	1,5	1,5	1,5		0,6	0,6		
4	3	3	3	3	1,2	1,2	1,2	
6	5,5	5,5	5,5	5,5	2	2	2	2
8	8	8	8	8	3	3	3	3

Table 18 – Minimum creepage distances

Rated insulation voltage of equipment or working voltage a.c., r.m.s. or d.c.	Creepage distances for equipment subject to long-term stress mm												
	Pollution degree			Pollution degree			Pollution degree			Pollution degree			
	1 [f]	2 [f]	1	2			3			4			
	Material group			Material group			Material group			Material group			
V [e]	[b]	[c]	[b]	I [a]	II	IIIa IIIb	I	II	IIIa IIIb	I	II	IIIa	IIIb
10	0,025	0,04	0,08	0,4	0,4	0,4	1	1	1	1,6	1,6	1,6	
12,5	0,025	0,04	0,09	0,42	0,42	0,42	1,05	1,05	1,05	1,6	1,6	1,6	
16	0,025	0,04	0,1	0,45	0,45	0,45	1,1	1,1	1,1	1,6	1,6	1,6	
20	0,025	0,04	0,11	0,48	0,48	0,48	1,2	1,2	1,2	1,6	1,6	1,6	
25	0,025	0,04	0,125	0,5	0,5	0,5	1,25	1,25	1,25	1,7	1,7	1,7	
32	0,025	0,04	0,14	0,53	0,53	0,53	1,3	1,3	1,3	1,8	1,8	1,8	
40	0,025	0,04	0,16	0,56	0,8	1,1	1,4	1,6	1,8	1,9	2,4	3	
50	0,025	0,04	0,18	0,6	0,85	1,2	1,5	1,7	1,9	2	2,5	3,2	
63	0,04	0,063	0,2	0,63	0,9	1,25	1,6	1,8	2	2,1	2,6	3,4	[d]
80	0,063	0,1	0,22	0,67	0,95	1,3	1,7	1,9	2,1	2,2	2,8	3,6	
100	0,1	0,16	0,25	0,71	1	1,4	1,8	2	2,2	2,4	3,0	3,8	
125	0,16	0,25	0,28	0,75	1,05	1,5	1,9	2,1	2,4	2,5	3,2	4	
160	0,25	0,4	0,32	0,8	1,1	1,6	2	2,2	2,5	3,2	4	5	
200	0,4	0,63	0,42	1	1,4	2	2,5	2,8	3,2	4	5	6,3	
250	0,56	1	0,56	1,25	1,8	2,5	3,2	3,6	4	5	6,3	8	
320	0,75	1,6	0,75	1,6	2,2	3,2	4	4,5	5	6,3	8	10	
400	1	2	1	2	2,8	4	5	5,6	6,3	8	10	12,5	

[a] Material group I or material groups II, IIIa, IIIb where likelihood to track is reduced due to the conditions of IEC 60664-1.

[b] Material groups I, II, IIIa, IIIb.

[c] Material groups I, II, IIIa.

[d] Values of creepage distances in this area have not been established. Material group IIIb is in general not recommended for application in pollution degree 4.

[e] As an exception, for rated insulation voltages 127, 208, 415 and 440 V, creepage distances corresponding to the lower values 125, 200, 400 V respectively may be used.

[f] The values given in these two columns apply to creepage distances of printed wiring materials.

Table 19 – Dielectric test voltage corresponding to the rated insulation voltage

Rated insulation voltage U_i V	a.c. test voltage (r.m.s.) V	d.c. test voltage [a, b] V
$U_i \leq 60$	1 000	1 415
$60 < U_i \leq 300$	1 500	2 120
$300 < U_i \leq 440$	1 640	2 320

[a] Test voltages based on 6.1.3.4.1, 5th paragraph of IEC 60664-1:2007.

[b] A direct current test voltage may be used only if an alternating test voltage cannot be applied. See also item c) 2) ii) of 9.3.3.4.1.

9.3.3.5 Making and breaking capacities

9.3.3.5.1 General test conditions

Tests for verification of making and breaking capacities shall be made according to the general test conditions stated in 9.3.2.1.

Four-pole contactors shall be tested as three-pole contactors with the unused pole, which in the case of contactors provided with a neutral pole is the neutral pole, connected to the frame. One test on three adjacent poles is sufficient.

The tests shall be made under the operating conditions stated in Table 7 without failure (see 9.3.3.5.4, item b)).

The control supply voltage shall be 100 % of U_s for the test of utilization categories AC-7a and AC-7c. For the test of utilization category AC-7b, it shall be 110 % of U_s for half the number of operating cycles and 85 % of U_s for the other half.

Connections to the main circuit shall be similar to those intended to be used when the contactor is in service. If necessary, or for convenience, the control and auxiliary circuits, and in particular the coil of the contactor, may be supplied by an independent source. Such a source shall deliver the same kind of current and the same voltage as specified for service conditions.

9.3.3.5.2 Test circuit

a) Figure 11, Figure 12, Figure 13 and Figure 14 give diagrams of the circuits to be used for the tests concerning:
   - single-pole contactors on single-phase a.c. (Figure 11);
   - two-pole contactors on single-phase a.c. (Figure 12);
   - three-pole contactors or three single-phase contactors on three-phase a.c. (Figure 13);
   - four-pole contactors on three-phase four wire a.c. (Figure 14).

   A detailed diagram of the circuit used for the test shall be given in the test report.
b) The prospective current at the supply terminals of the contactor shall be not less than 10 times the test current.
c) The test circuit comprises the supply source, the contactor D under test and the load circuit.
d) 1) Utilization categories AC-7a and AC-7b:

The load circuit shall consist of resistors and air-cored reactors in series. Air-cored reactors in any phase shall be shunted by resistors taking approximately 0,6 % of the current through the reactor.

However, where a transient recovery voltage is specified, instead of the 0,6 % shunt resistors, parallel resistors and capacitors shall be included across the load, the complete, load circuit being as shown in Figure 16.

2) Utilization category AC-7c:

The diagram of the circuit is given under Figure 22. The prospective short-circuit current of the supply shall be between 3 kA and 4 kA at cos φ = 0,90 ± 0,05.

The load circuit shall consist of resistors and air-cored reactors in series and capacitors in parallel.

The line resistor R_1 consists in a twin-core cable of 2 x 12,5 m in length with wires cross-section appropriate to the rated current.

The load circuit consists of:

– a compensated capacitor value C_p of 10 µF (-0 µF; +2 µF) per A.

Ex: for 10 A, C_p = 100 µF; for 20 A, C_p = 200 µF.

The capacitors shall be connected with 2,5 mm^2 conductors having the shortest possible length;

– an inductor, X, and a resistor, R, adjusted to give to the load circuit (comprising C_p, R and X) the power factor and the test current according to Table 7 and Table 9.

e) The loads shall be adjusted to obtain, at the specified voltage:

– the value of current, power-factor and power frequency recovery voltage specified in Table 7;

– when specified, the oscillatory frequency of the transient recovery voltage and the value of the factor γ.

The factor γ is the ratio of the value U_1 of the highest peak of the transient recovery voltage to the instantaneous value U_2, at the instant of current zero, of the component of the recovery voltage at power frequency (see Figure 15).

f) The test circuit shall be earthed at one unique point and the position of this point shall be stated in the test report.

g) All parts of the contactor normally earthed in service, including the enclosure or the screens, shall be insulated from earth and connected as indicated in Figure 11, Figure 12, Figure 13 or Figure 14.

This connection shall comprise a fusible element F consisting of a copper wire 0,8 mm in diameter and at least 50 mm long, or an equivalent fusible element, for the detection of the fault current.

The prospective fault current in the fusible-element circuit shall be 1 500 A ± 10 %, except as stated in Note 2 and Note 3. If necessary, a resistor limiting the current to that value shall be used.

NOTE 1 A copper wire of 0,8 mm in diameter will melt at 1 500 A in approximately half a cycle at a frequency between 45 Hz to 67 Hz.

NOTE 2 The prospective fault current may be less than 1 500 A, with a smaller diameter copper wire (see Note 4) corresponding to the same melting time as in Note 1.

NOTE 3 In the case of a supply having an artificial neutral, a lower prospective fault current may be accepted, subject to the agreement of the manufacturer, with a smaller diameter copper wire (see Note 4) corresponding to the same melting time as in Note 1.

NOTE 4 The relationship between the prospective fault current in the fusible element circuit and the diameter of the copper wire should be in accordance with the table below:

Diameter of copper wire mm	**Prospective fault current in the fusible element circuit** A
0,1	50
0,2	150
0,3	300
0,4	500
0,5	800
0,8	1 500

9.3.3.5.3 Characteristics of transient recovery voltage

The following requirements apply to contactors of utilization category AC-7b.

To simulate the conditions in circuits including individual motor loads (inductive loads), the oscillatory frequency of the transient recovery voltage of the load circuit shall be adjusted to the value:

$$f = 2\,000 \times I_c^{\,0,2} \times U_e^{\,-0,8} \pm 10\ \%$$

where

f is the oscillatory frequency, in kilohertz ;

I_c is the breaking current, in amperes ;

U_e is the rated operational voltage of the equipment, in volts.

The factor γ shall be adjusted to the value:

$$\gamma = 1,1 \pm 0,05.$$

The value of reactance necessary for the test may be obtained by coupling several reactors in parallel on condition that the transient recovery voltage can still be considered as having only one oscillatory frequency. This is generally the case when the reactors have practically the same time-constant.

The load terminals of the contactor shall be connected as closely as possible to the terminals of the adjusted load circuit. The adjustment should be made with these connections in place.

Adjustment of the transient recovery voltage shall be made on the whole load circuit and, in particular, the earth point shall not be moved between the adjustment and the test.

A procedure for adjusting the load circuit is given in Annex C.

9.3.3.5.4 Rated making and breaking capacities

a) Rated making and breaking capacities of contactors

   The contactor shall make and break the current corresponding to its utilization category and for the number of operating cycles given in Table 7.

b) Behaviour of the contactor during and condition after the making and breaking capacity tests.

During the tests within the limits of the specified making and breaking capacities of 9.3.3.5 and the verification of conventional operational performance of 9.3.3.6.2, there shall be no permanent arcing, no flash-over between poles, no blowing of the fusible element in the earth circuit (see 9.3.3.5.2) and no welding of the contacts.

After the tests, the dielectric properties of the contactor shall be verified by a dielectric test as specified in 9.3.3.4.1, item d).

The contacts shall operate when the contactor is switched by the applicable method of control.

9.3.3.6 Operational performance capability

9.3.3.6.1 General

Tests concerning the verification of conventional operational performance are intended to verify that a contactor is capable of fulfilling the requirements given in Table 9.

Connections to the main circuit shall be similar to those intended to be used when the contactor is in service.

The test circuit given in 9.3.3.5.2 is applicable and the load is to be tuned according to 9.3.3.5.3.

The control voltage shall be 100 % of the rated control supply voltage.

9.3.3.6.2 Conventional operational performance of contactors

The contactor shall make and break the current corresponding to its utilization category and for the number of operating cycles given in Table 9.

9.3.3.6.3 Behaviour of the contactor during and condition after the conventional operational performance tests

The requirement of 9.3.3.5.4, item b), should be fulfilled and the dielectric properties of the contactor shall be verified by a dielectric test as specified in 9.3.3.4.1, item d).

9.3.4 Performance under short-circuit conditions

9.3.4.1 General

This subclause specifies test conditions for verification of compliance with the requirements of 8.2.5. Specific requirements regarding test procedure, test sequence, condition of contactor after the test are given in 9.3.4.2 and 9.3.4.3.

9.3.4.2 General conditions for short-circuit tests

9.3.4.2.1 General requirements for short-circuit tests

The general requirements of 9.3.2.1 apply. The contactor shall be operated under the conditions specified in 8.2.1. It shall be verified that the contactor operates correctly on no-load when it is operated under the above conditions.

9.3.4.2.2 Test circuit

a) Figure 17, Figure 18, Figure 19 and Figure 20 give diagrams of the circuits to be used for the tests concerning:
   – single-pole contactors on single-phase a.c. (Figure 17);
   – two-pole contactors on single-phase a.c. (Figure 18);
   – three-pole contactors on three-phase a.c. (Figure 19);

– four-pole contactors on three-phase four wire a.c. (Figure 20).

A detailed diagram of the circuit used for the test shall be given in the test report.

b) The supply S feeds a circuit including resistors R_1, reactors X and the contactor D under test.

In all cases the supply shall have sufficient power to permit the verification of the characteristics given by the manufacturer.

The resistance and reactance of the test circuit shall be adjustable to satisfy the specified test conditions. The reactors X shall be air-cored. They shall be connected in series with the resistors R_1, and their value shall be obtained by series coupling of individual reactors; parallel connecting of reactors is permitted when these reactors have practically the same time-constant.

Since the transient recovery voltage characteristics of the test circuits including large air-cored reactors are not representative of usual service conditions, the air-cored reactor in each phase shall be shunted by a resistor taking approximately 0,6 % of the current through the reactor, unless otherwise agreed between manufacturer and user.

c) In each test circuit (Figure 17, Figure 18, Figure 19 and Figure 20), the resistors and reactances are inserted between the supply source S and the contactor D under test. The positions of the closing device A and the current sensing devices (I_1, I_2, I_3) may be different. The connection of the contactor under test to the test circuit shall be stated in the test report.

When tests are made with current less than the rated value, the additional impedances required shall normally be inserted on the load side of the contactor between it and the short-circuit; they may, however, be inserted on the line side, in which case this shall be stated in the test report.

Unless a special agreement has been drawn up between manufacturer and user and details noted in the test report, the diagram of the test circuit shall be in accordance with the figures.

There shall be one and only one point of the test circuit which is earthed; this may be the short-circuit link of the test circuit or the neutral point of the supply or any other convenient point, but the method of earthing shall be stated in the test report.

d) All parts of the contactor normally earthed in service, including the enclosure or the screens, shall be insulated from earth and connected to a point, as indicated in Figure 17, Figure 18, Figure 19 and Figure 20.

This connection shall comprise a fusible element F consisting of a copper wire 0,8 mm in diameter and at least 50 mm long, or of an equivalent fusible element for the detection of the fault current.

The prospective fault current in the fusible-element circuit shall be 1 500 A ± 10 %, except as stated in Note 2 and Note 3. If necessary, a resistor limiting the current to that value shall be used.

NOTE 1 A copper wire of 0,8 mm in diameter will melt at 1 500 A in approximately half a cycle at a frequency between 45 Hz to 67 Hz.

NOTE 2 The prospective fault current may be less than 1 500 A, with a smaller diameter copper wire (see Note 4) corresponding to the same melting time as in Note 1.

NOTE 3 In the case of a supply having an artificial neutral, a lower prospective fault current may be accepted, subject to the agreement of the manufacturer, with a smaller diameter copper wire (see Note 4) corresponding to the same melting time as in Note 1.

NOTE 4 The relationship between the prospective fault current in the fusible element circuit and the diameter of the copper wire should be in accordance with the table below:

Diameter of copper wire mm	**Prospective fault current in the fusible element circuit** A
0,1	50
0,2	150
0,3	300
0,4	500
0,5	800
0,8	1 500

9.3.4.2.3 Power-factor of the test circuit

The power-factor of each phase of the test circuit should be determined according to an established method which shall be stated in the test report.

Two examples are given in Annex D.

The power-factor of a polyphase circuit is considered as the mean value of the power-factors of each phase.

The power-factor shall be in accordance with Table 20.

The difference between the mean value and the maximum and minimum values of the power-factors in the different phases shall remain within ±0,05.

Table 20 – Values of power-factors corresponding to test currents and ratio *n* between peak and r.m.s. values of current

Test current A	**Power-factor**	*n*
$I \leq 1\,500$	0,95	1,41
$1\,500 < I \leq 3\,000$	0,9	1,42
$3\,000 < I \leq 4\,500$	0,8	1,47
$4\,500 < I \leq 6\,000$	0,7	1,53

9.3.4.2.4 Calibration of the test circuit

The calibration of the test circuit is carried out by placing temporary connections B of negligible impedance as close as reasonably possible to the terminals provided for connecting the equipment under test.

Resistors R_1 and reactors X are adjusted so as to obtain, at the applied voltage, a current equal to the rated short-circuit breaking capacity as well as the power-factor indicated in 9.3.4.2.3.

In order to determine the short-circuit making capacity of the contactor under test from the calibration oscillogram, it is necessary to calibrate the circuit so as to ensure that the prospective making current is achieved in one of the phases.

NOTE The applied voltage is the open circuit voltage necessary to produce the specified power frequency recovery voltage (but see also Note 1 of 9.3.2.2.3).

The test circuit is energized simultaneously in all poles and the current curve is recorded for a duration of at least 0,1 s.

9.3.4.2.5 Test procedure

After calibration of the test circuit in accordance with 9.3.4.2.4, the temporary connections are replaced by the contactor under test, and its connecting cables, if any.

The contactor and its associated SCPD shall be mounted and connected as in normal use. They shall be connected to the circuit using a maximum of 2,4 m of cable (corresponding to the operational current) for each main circuit.

Three phase tests are considered to cover single-phase applications.

9.3.4.2.6 Interpretation of records

a) *Determination of the applied voltage and power-frequency recovery voltage*

   The applied voltage and the power-frequency recovery voltage are determined from the record corresponding to the break test made with the contactor under test, and evaluated as indicated in Figure 21.

   The voltage on the supply side shall be measured during the first complete cycle after arc extinction in all poles and after high frequency phenomena have subsided (see Figure 21).

b) *Determination of the prospective breaking current*

   This determination is made by comparing the current curves recorded during the calibration of the circuit with those recorded during the break test of the contactor (see Figure 21).

   The a.c. component of the prospective breaking current is taken as being equal to the r.m.s. value of the a.c. component of the calibration current at the instant which corresponds to the separation of the arcing contacts (value corresponding to $A_2/2\sqrt{2}$ of Figure 21, item a)). The prospective breaking current shall be the average of the prospective currents in all phases; the prospective current in any phase shall not vary from the average by more than 10 % of the average.

c) *Determination of the prospective peak making current*

   The prospective peak making current is determined from the calibration record and its value shall be taken as being that corresponding to A_1 of Figure 21, item a). In the case of a three-phase test it shall be taken as the highest of the three A_1 values obtained from the record.

   NOTE For tests on single-pole contactors, the prospective peak making current determined from the calibration record may differ from the value of the actual making current corresponding to the test, depending on the instant of making.

9.3.4.3 Conditional short-circuit current

9.3.4.3.1 General

The contactor and the associated SCPD shall be subjected to the tests given in 9.3.4.3.2 and 9.3.4.3.3. The tests shall be so conducted that conditions of maximum I_e and of maximum U_e are covered.

For a magnetically operated contactor, the magnet shall be held closed by a separate electrical supply at the specified control voltage. The SCPD used shall be as stated in 8.2.5. If the SCPD is a circuit-breaker with an adjustable current setting, the test shall be made with the circuit-breaker adjusted to the maximum setting.

During the test, all openings of the enclosure shall be closed as in normal service and the door or cover secured by the means provided.

A new sample may be used for each operation of the test sequences at prospective currents I_r and I_q.

9.3.4.3.2 Test at the prospective current I_r

The circuit shall be adjusted to the prospective test current corresponding to the rated operational current I_e according to Table 21.

The contactor and the associated SCPD shall then be connected to the circuit. The following sequence of operations shall be performed:

1) One breaking operation of the SCPD shall be performed with SCPD and the contactor closed prior to the test.
2) One breaking operation of the SCPD shall be performed by closing the contactor on to the short-circuit.

Table 21 – Value of the prospective test current according to the rated operational current

Rated operational current I_e A	Prospective current I_r kA
$0 < I_e \leq 16$	1
$16 < I_e \leq 63$	3

The power factor shall be according to Table 20 of 9.3.4.2.3.

9.3.4.3.3 Test at the rated conditional short-circuit I_q

This test is done if the current I_q is higher than the current I_r.

The circuit shall be adjusted to the prospective short-circuit I_q equal to the rated conditional short-circuit current.

If the SCPD is a fuse and the test current is within the current-limiting range of the fuse then, if possible, the fuse shall be selected to permit the maximum let through peak current I_p and I^2t.

The contactor and the associated SCPD shall then be connected to the circuit.

The following sequence of operations shall be performed:

1) One breaking operation of the SCPD shall be performed with SCPD and the contactor closed prior to the test.
2) One breaking operation of the SCPD shall be performed by closing the contactor on to the short-circuit.

9.3.4.3.4 Results to be obtained

The contactor shall be considered to have passed the tests at the prospective current I_r and, where applicable, the prospective current I_q if the following conditions are met:

A The fault current has been successfully interrupted by the SCPD and the fuse or fuse element or solid connection between the enclosure and supply shall not have melted.

B The door or cover of the enclosure has not been blown open, and it is possible to open the door or cover. Deformation of enclosure is considered acceptable provided that the degree of protection by the enclosure is not less than IP2X.

C There is no damage to the conductors or terminals and no conductor has been separated from the terminals.

D There is no cracking or breaking of an insulating base to the extent that the integrity of mounting of a live part is impaired.

E There has been no discharge of parts beyond the enclosure. Damage to the contactor is acceptable and the contactor may be unsuitable for further use.

9.3.5 Overload current withstand capability

For the test, the contactor shall be mounted, wired and operated as specified in 9.3.2.

All poles of the contactor are simultaneously subjected to one test with the overload current and duration values stated in 8.2.4.4. The test is performed at any convenient voltage and it starts with the contactor at room temperature.

After the test, the contactor shall be substantially in the same condition as before the test. This is verified by visual inspection.

NOTE The I^2t value (Joule integral) calculated from this test cannot be used to estimate the performance of the contactor under short-circuit conditions.

9.3.6 Routine tests

Routine tests are tests to which each individual contactor is subjected during or after manufacture to ascertain whether it complies with the stated requirements.

9.3.6.1 General

Routine tests shall be carried out under the same or equivalent conditions to those specified for type tests in the relevant parts of 9.1.2. However, the limits of operation in 9.3.3.2 may be verified at the prevailing ambient air temperature but a correction may be necessary to allow for the normal ambient conditions.

9.3.6.2 Operation and operating limits

Tests are carried out to verify operation within the limits specified in 8.2.1.2.

NOTE In these tests it is not necessary to reach thermal equilibrium.

9.3.6.3 Dielectric tests

Subclause 9.3.3.4.2 applies.

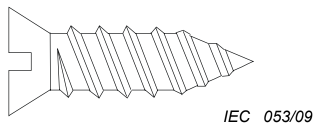


Figure 1 – Thread-forming tapping screw

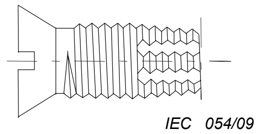


Figure 2 – Thread-cutting tapping screw

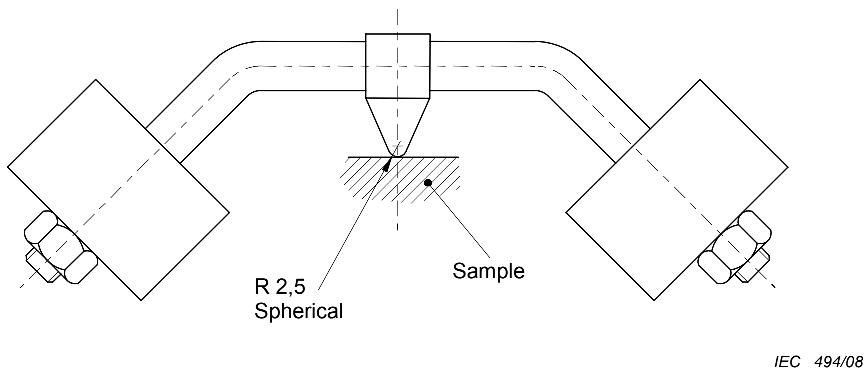
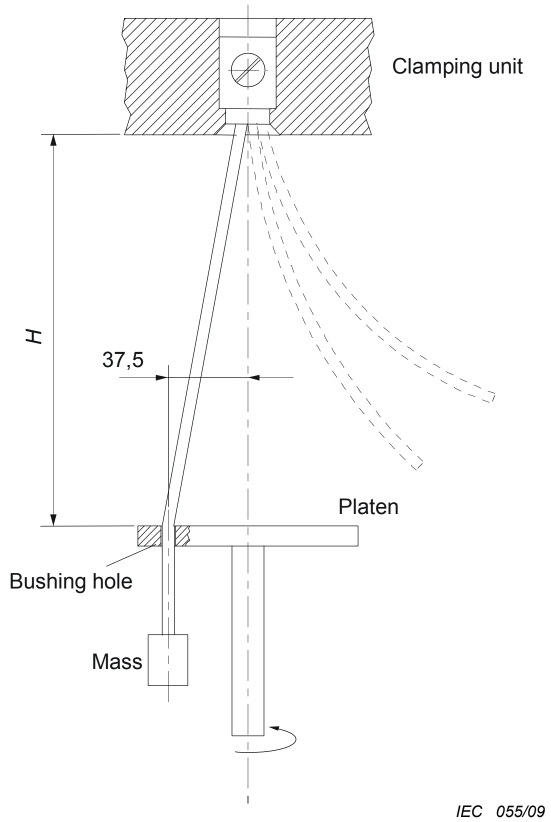
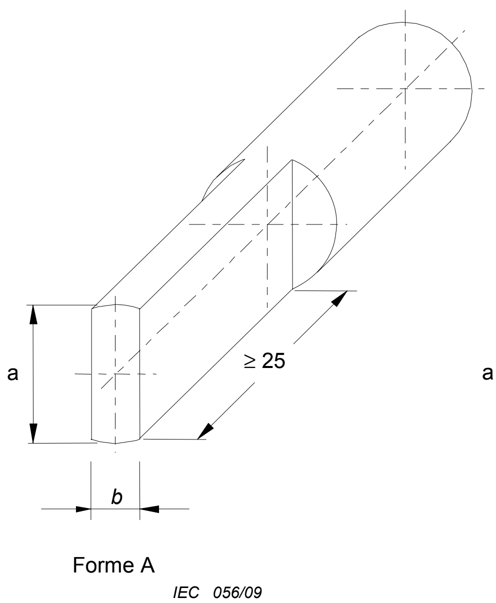


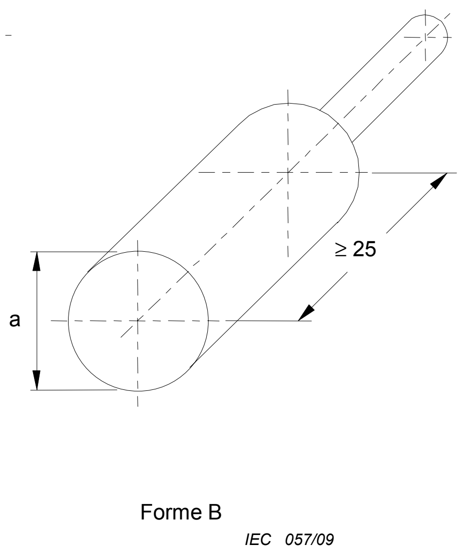
Figure 3 – Ball-pressure test apparatus (see 9.2.2.3.1)



Dimensions in millimetres

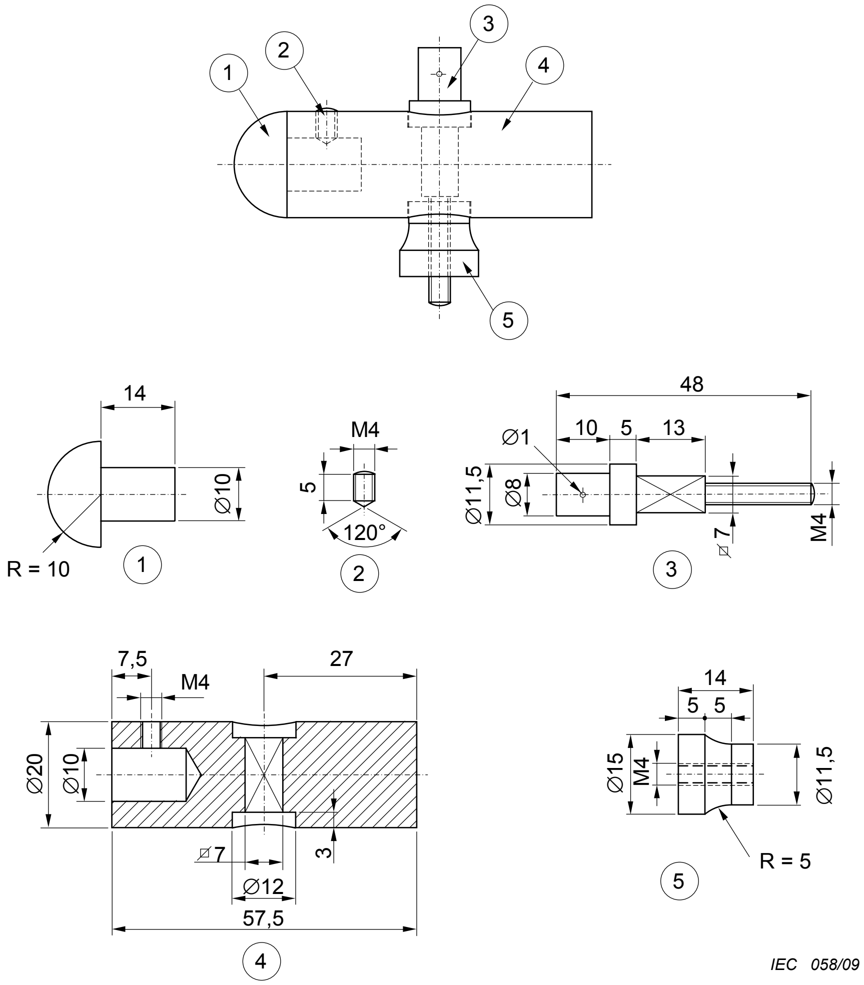
Figure 4 – Test equipment for flexion test (see 9.2.5.3)





Dimensions in millimetres

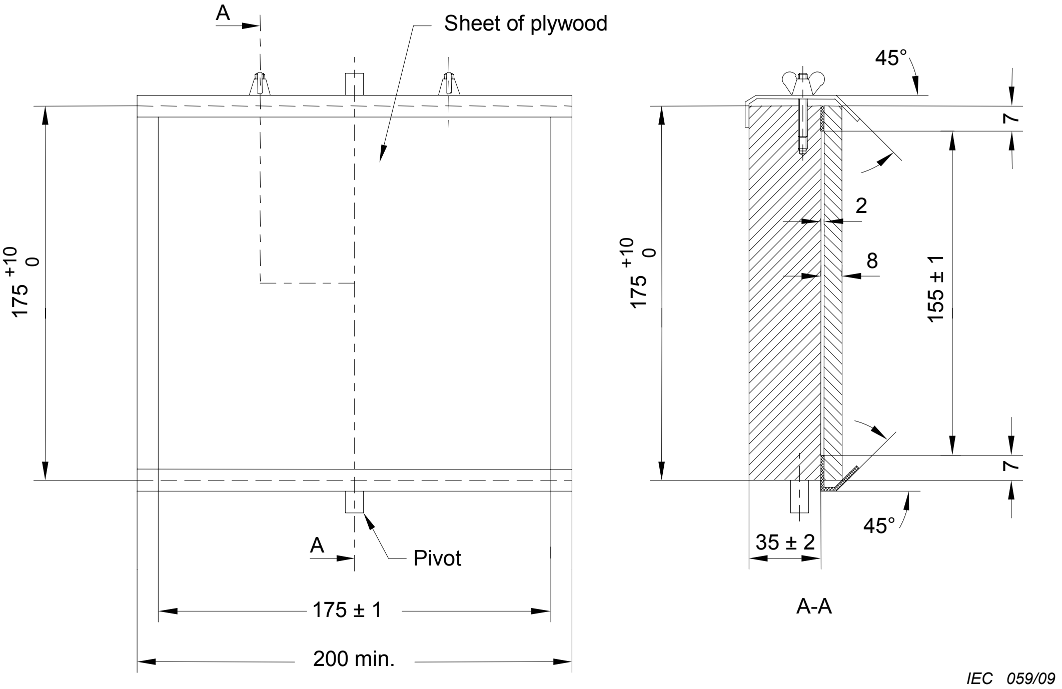
Figure 5 – Gauges of form A and form B (see 9.2.5.5)



Dimensions in millimetres

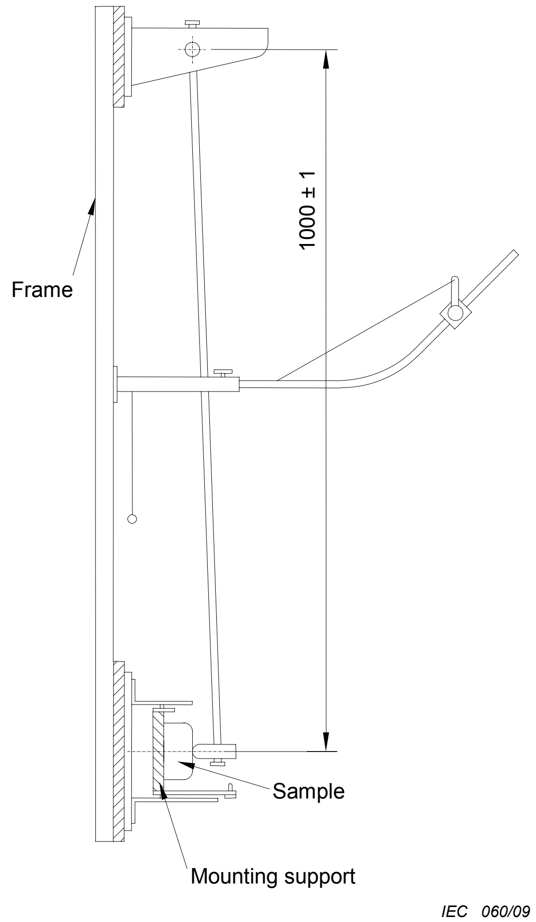
Key:
1 Polyamide
2, 3, 4, 5 Steel Fe 360

Figure 6 – Pendulum for mechanical impact test apparatus (striking element) (see 9.2.6.2.1)



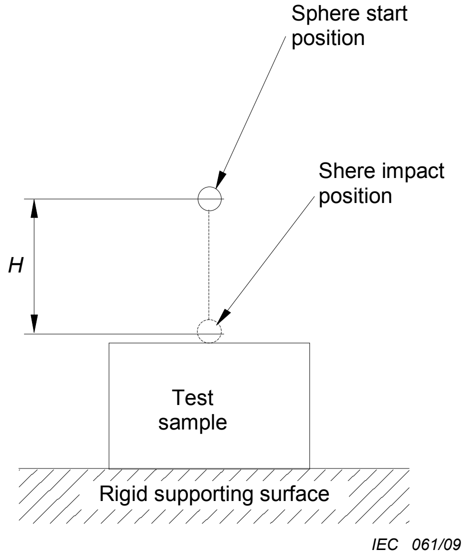
Dimensions in millimetres

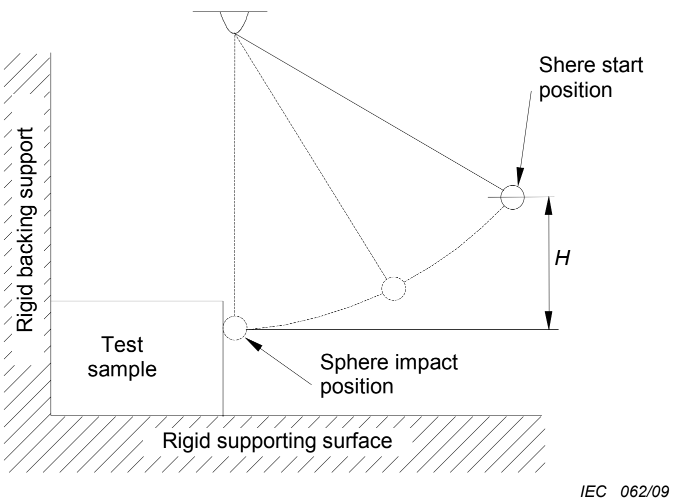
Figure 7 – Mounting support for sample, for mechanical impact test (see 9.2.6.2.1)



Dimensions in millimetres

Figure 8 – Pendulum hammer test apparatus (see 9.2.6.2.1)

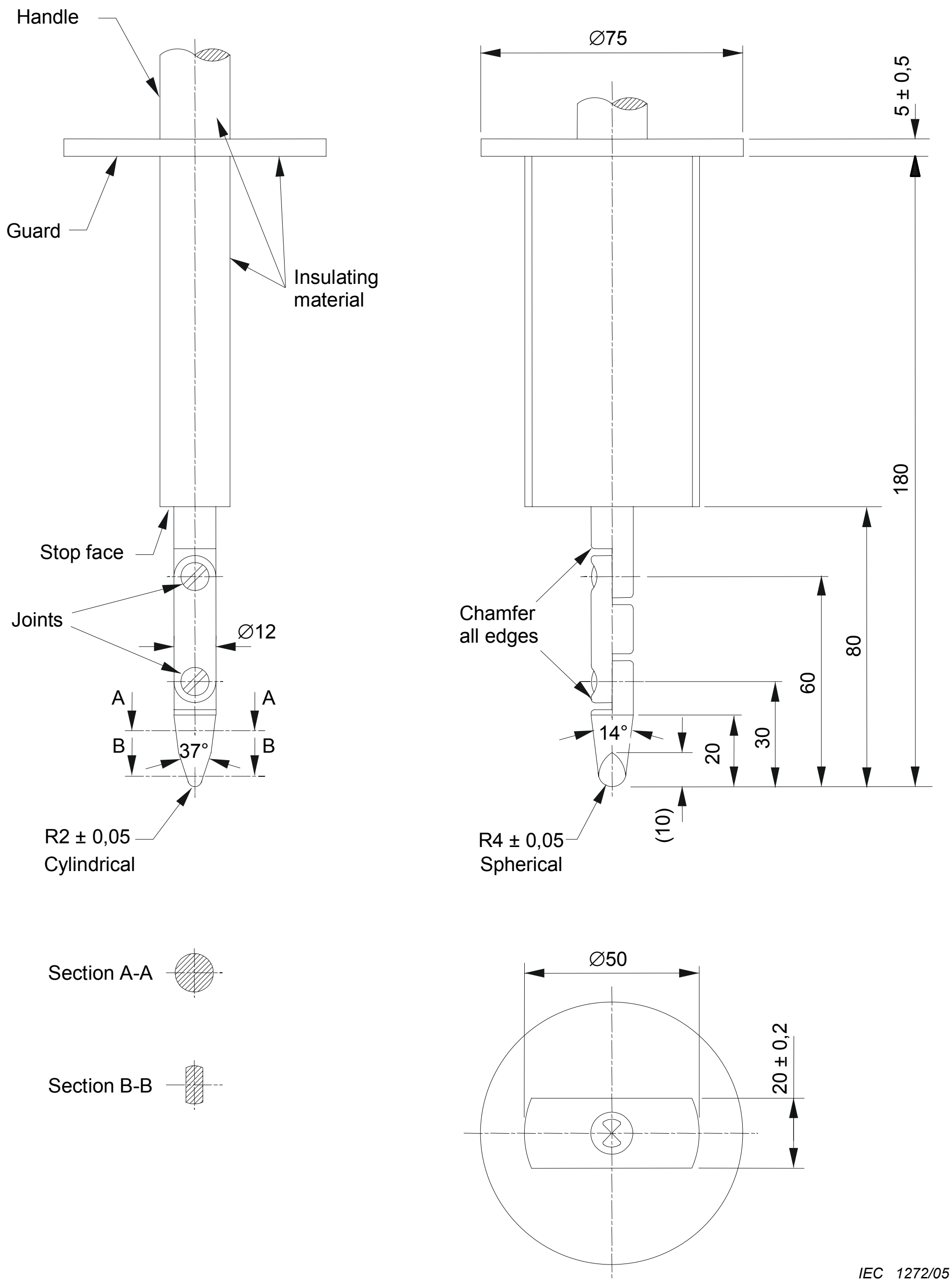




NOTE *H* = 1 300 mm.

For the ball pendulum impact test, the sphere must contact the test sample when the cord is in the vertical position as shown.

Figure 9 – Sphere test apparatus (see 9.2.6.2.2)



Dimensions in millimetres

Material: metal, except where otherwise specified

Linear dimensions in millimetres

Tolerances on dimensions without specific tolerance:

on angles: 0/-10'

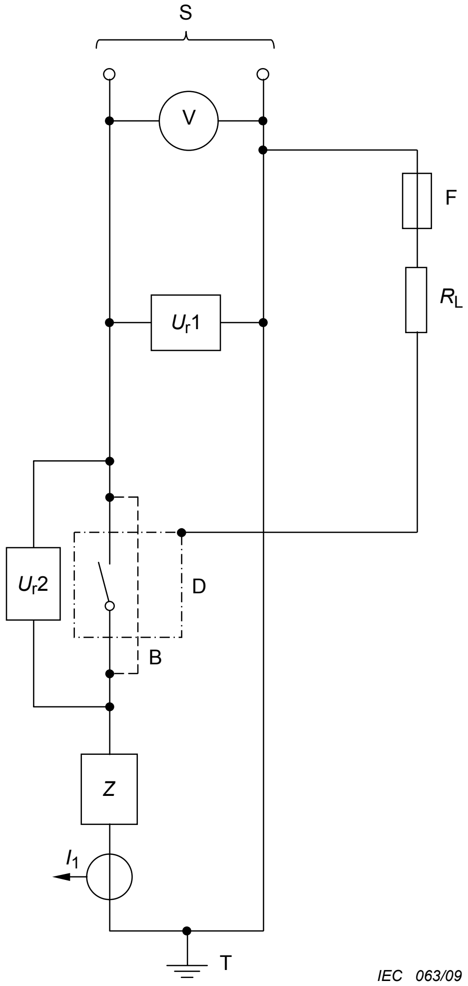
on linear dimensions:

up to 25 mm: 0/-0,05

over 25 mm: ±0,2

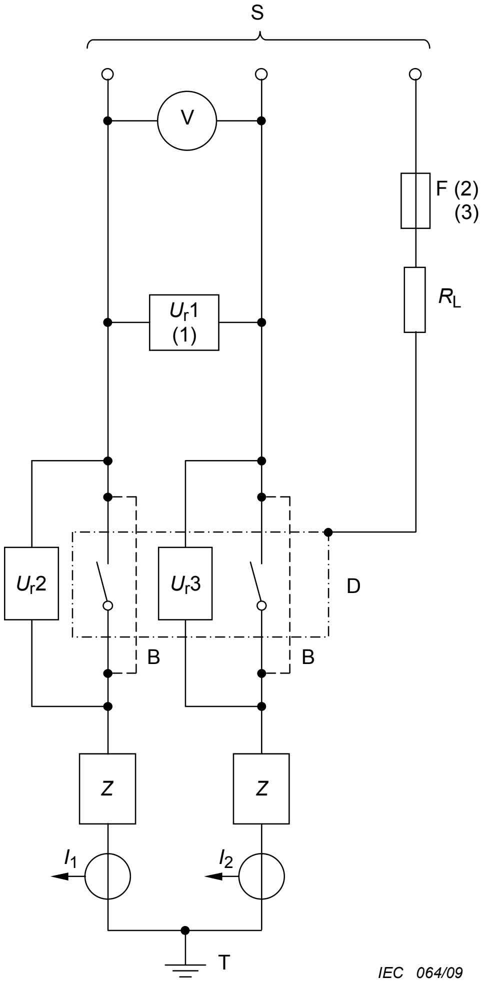
Both joints shall permit movement in the same plane and the same direction through an angle of 90° with a 0 to +10° tolerance.

Figure 10 – Jointed test finger (according to IEC 60529)



S	=	Supply
U_r1, U_r2	=	Voltage sensors
F	=	Fusible element (see 9.3.3.5.2, g))
Z	=	Load circuit (see Figure 16)
R_L	=	Fault current limiting resistor
D	=	Contactor under test (including connecting cables)
B	=	Temporary connections for calibration
I_1	=	Current sensor
T	=	Earth – One earthing point only (load side or supply side)

Figure 11 – Diagram of the test circuit for the verification of making and breaking capacities of a single-pole contactor on single-phase a.c.



S	=	Supply
U_r1, U_r2, U_r3	=	Voltage sensors
V	=	Voltage measuring device
N	=	Neutral of supply (or artificial neutral)
F	=	Fusible element (see 9.3.3.5.2. g))
Z	=	Load circuit (see Figure 16)
R_L	=	Fault current limiting resistor
D	=	Contactor under test (including connecting cables)
B	=	Temporary connections for calibration
I_1, I_2	=	Current sensors
T	=	Earth – One earthing point only (load side or supply side)

NOTE 1 U_r1 may, alternatively, be connected between phase and neutral.

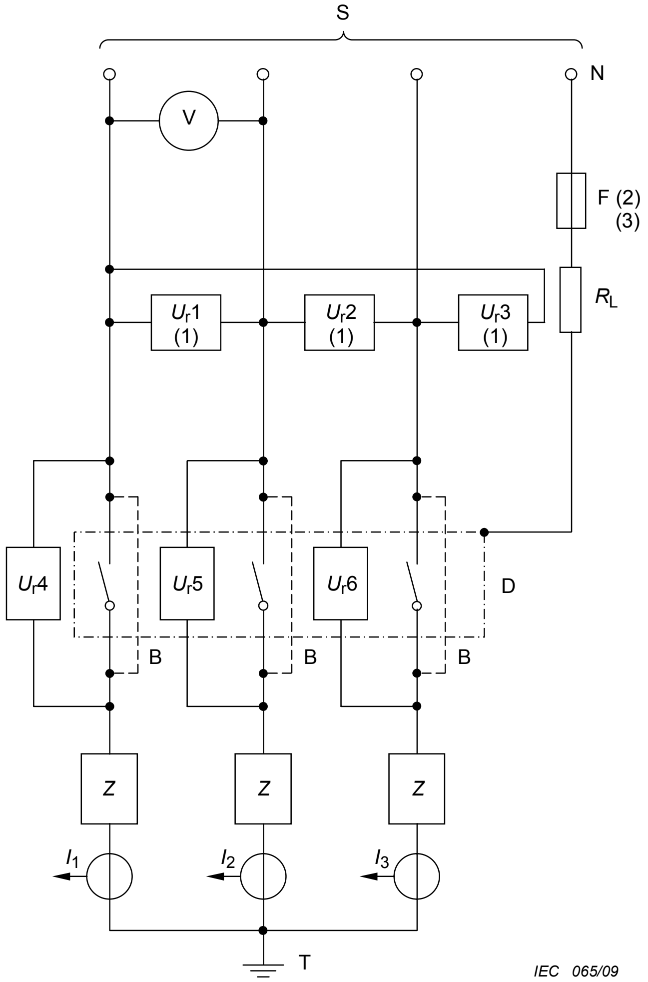
NOTE 2 In the case of equipment intended for use in phase-earthed systems or if this diagram is used for the test of the neutral and adjacent pole of a 4-pole equipment, F shall be connected to one phase of the supply.

NOTE 3 In the USA and Canada, F shall be connected:

– to one phase of the supply for equipment marked with a single value of U_e

– to the neutral for equipment marked with a twin voltage for U_e (see Note 1of 6.2).

Figure 12 – Diagram of the test circuit for the verification of making and breaking capacities of a two-pole contactor on single-phase a.c.



S	=	Supply
U_r1, U_r2, U_r3 U_r4, U_r5, U_r6	=	Voltage sensors
V	=	Voltage measuring device
N	=	Neutral of supply (or artificial neutral)
F	=	Fusible element (see 9.3.3.5.2. g))
Z	=	Load circuit (see Figure 16)
R_L	=	Fault current limiting resistor
D	=	Contactor under test (including connecting cables)
B	=	Temporary connections for calibration
I_1, I_2, I_3	=	Current sensors
T	=	Earth – One earthing point only (load side or supply side)

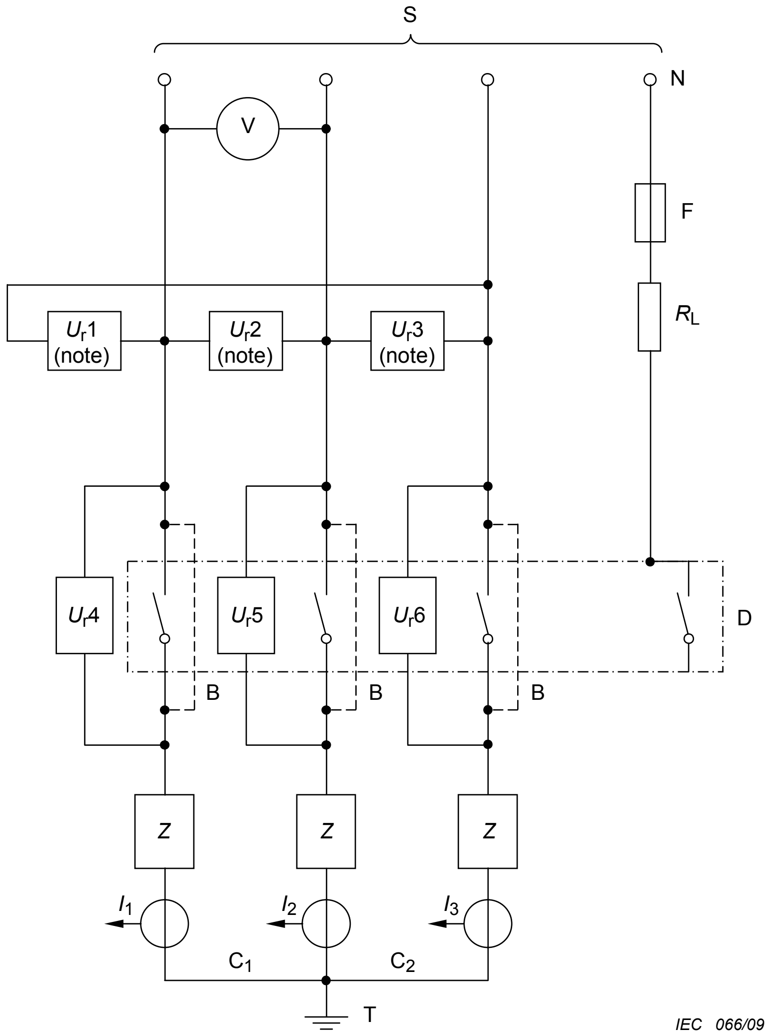
NOTE 1 U_r1, U_r2, U_r3 may, alternatively, be connected between phase and neutral.

NOTE 2 In the case of equipment intended for use in phase-earthed systems or if this diagram is used for the test of the neutral and adjacent pole of a 4-pole equipment, F shall be connected to one phase of the supply.

NOTE 3 In the USA and Canada, F shall be connected:

– to one phase of the supply for equipment marked with a single value of U_e
– to the neutral for equipment marked with a twin voltage for U_e (see Note 1 of 6.2).

Figure 13 – Diagram of the test circuit for the verification of making and breaking capacities of a three-pole contactor



S	=	Supply
U_r1, U_r2, U_r3 U_r4, U_r5, U_r6	=	Voltage sensors
V	=	Voltage measuring device
N	=	Neutral of supply (or artificial neutral)
F	=	Fusible element (see 9.3.3.5.2. g))
Z	=	Load circuit (see Figure 16)
R_L	=	Fault current limiting resistor
D	=	Contactor under test (including connecting cables)
B	=	Temporary connections for calibration
I_1, I_2, I_3	=	Current sensors
T	=	Earth – One earthing point only (load side or supply side)

NOTE U_r1, U_r2, U_r3 may, alternatively, be connected between phase and neutral.

Figure 14 – Diagram of the test circuit for the verification of making and breaking capacities of a four-pole contactor

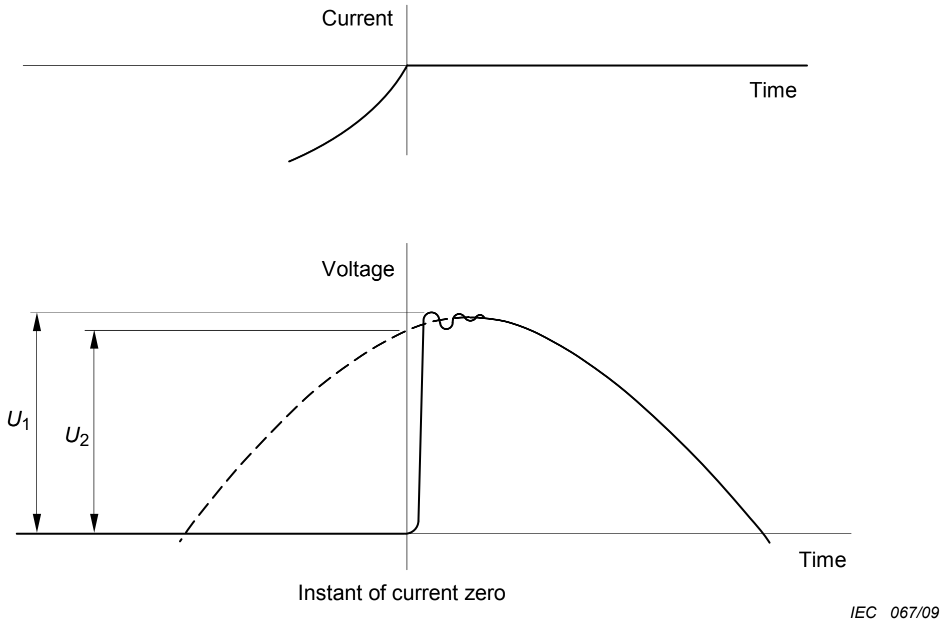
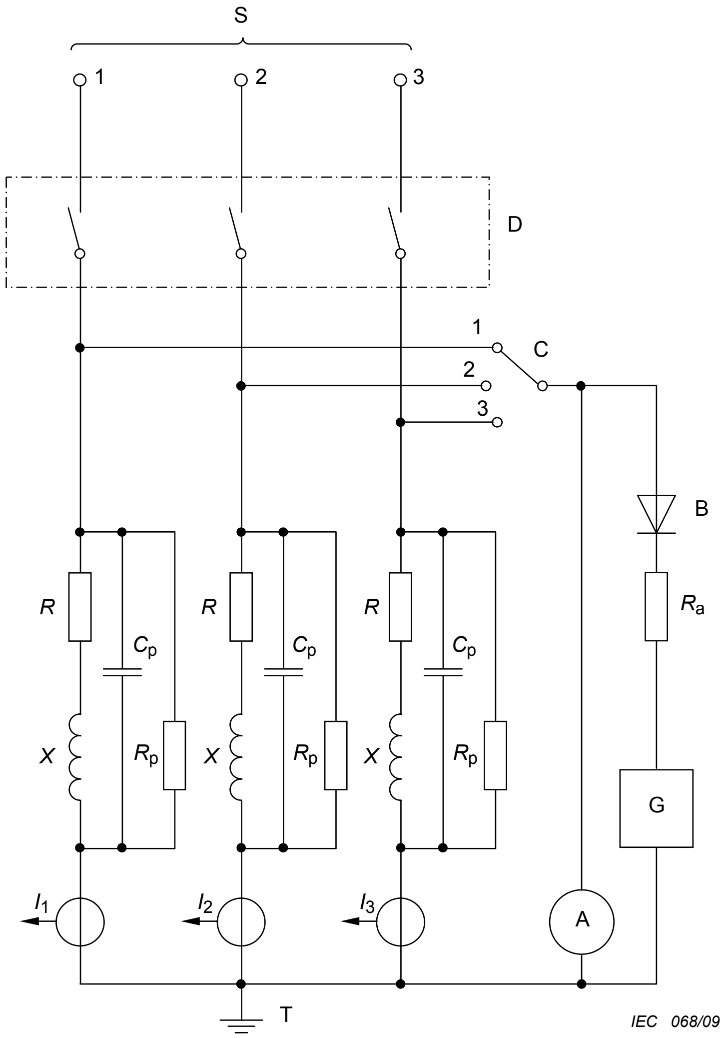


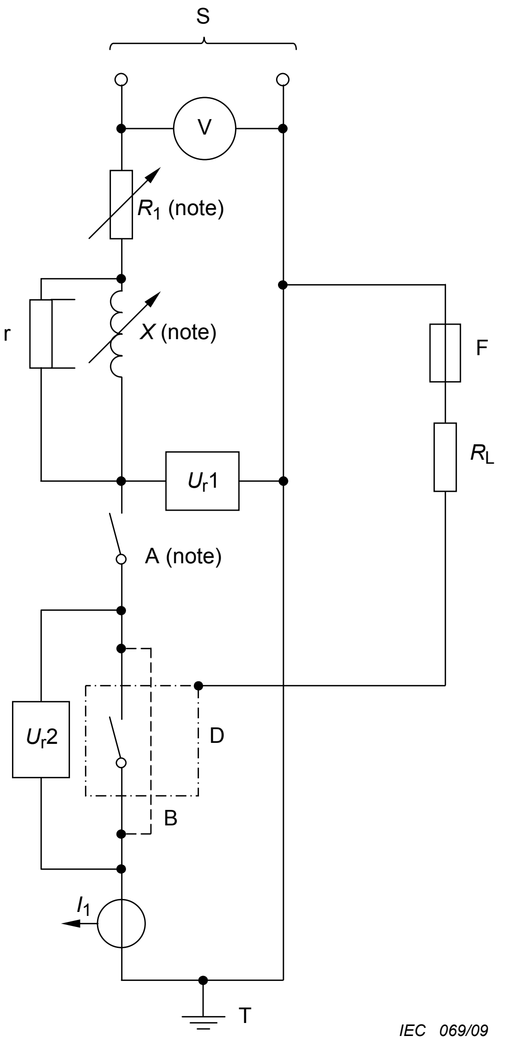
Figure 15 – Schematic illustration of the recovery voltage across contacts of the first phase to clear (see 9.3.3.5.2, e)) under ideal conditions



S	=	Supply
D	=	Contactor under test
C	=	Phase adjustment selector switch
B	=	Diode
A	=	Recorder
R_a	=	Resistor
G	=	High-frequency generator
R	=	Load circuit resistor
X	=	Load circuit reactor (see 9.3.3.5.2 d))
R_p	=	Resistors in parallel
C_p	=	Capacitors in parallel
I_1, I_2, I_3	=	Current sensors

The relative positions of the high-frequency generator (G) and of the diode (B) shall be as shown.

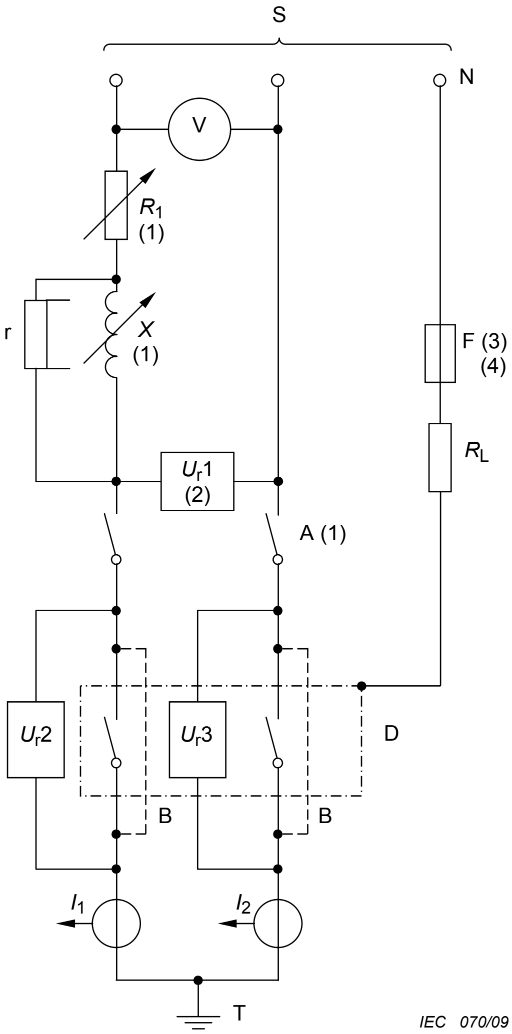
Figure 16 – Diagram of a load circuit adjustment method



S	=	Supply
U_r1, U_r2	=	Voltage sensors
V	=	Voltage measuring device
A	=	Closing device
R_1	=	Adjustable resistor
F	=	Fusible element (see 9.3.4.2.2 d))
X	=	Adjustable reactor
R_L	=	Fault current limiting resistor
D	=	Contactor under test (including connecting cables)
B	=	Temporary connection for calibration
I_1	=	Current sensor
T	=	Earth – One earthing point only (load side or supply side)
r	=	Shunt resistor (see 9.3.4.2.2 b))

NOTE Adjustable loads X and R_1 may be located either on the high voltage side or on the low voltage side of the supply circuit, the closing device A being located on the low voltage side.

Figure 17 – Diagram of the test circuit for the verification of short-circuit making and breaking capacities of a single-pole contactor on single-phase a.c.



S	=	Supply
U_r1, U_r2, U_r3	=	Voltage sensors
V	=	Voltage measuring device
A	=	Closing device
R_1	=	Adjustable resistor
N	=	Neutral of supply (or artificial neutral)
F	=	Fusible element (see 9.3.4.2.2 d))
X	=	Adjustable reactor
R_L	=	Fault current limiting resistor
D	=	Contactor under test (including connecting cables)
B	=	Temporary connection for calibration
I_1, I_2	=	Current sensors
T	=	Earth – One earthing point only (load side or supply side)
r	=	Shunt resistor (see 9.3.4.2.2 b))

NOTE 1 Adjustable loads X and R_1 may be located either on the high voltage side or on the low voltage side of the supply circuit, the closing device A being located on the low voltage side.

NOTE 2 U_r1 may, alternatively, be connected between phase and neutral.

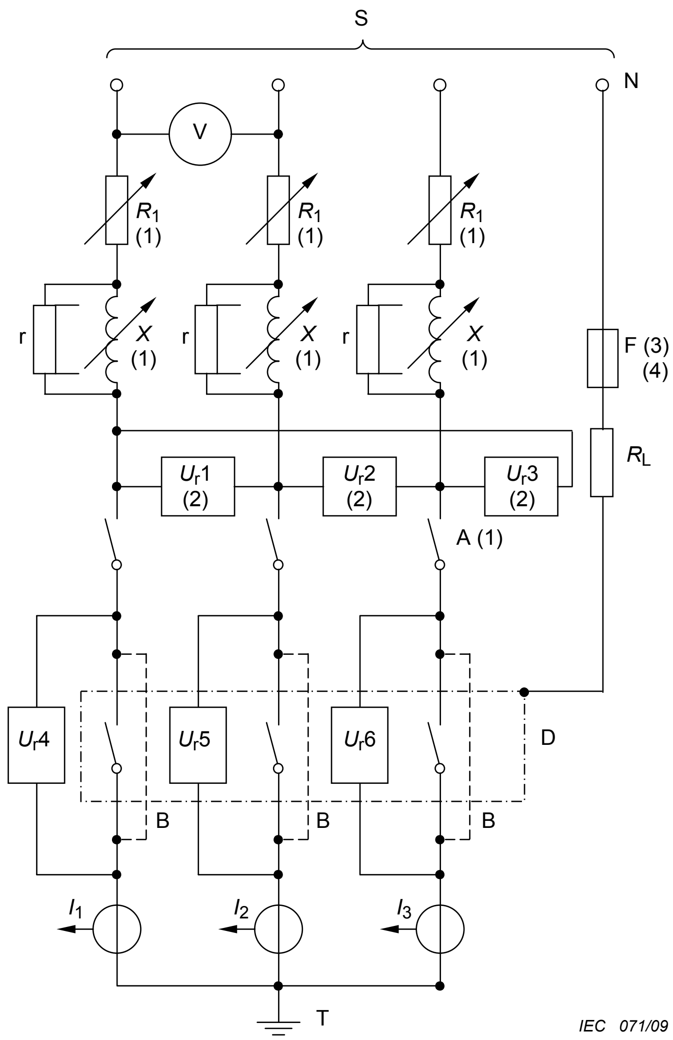
NOTE 3 In the case of equipment intended for use in phase-earthed systems or if this diagram is used for the test of the neutral and adjacent pole of a 4-pole equipment, F shall be connected to one phase of the supply.

NOTE 4 In the USA and Canada, F shall be connected:

– to one phase of the supply for equipment marked with a single value of U_e

– to the neutral for equipment marked with a twin voltage for U_e (see Note 1 to 6.2).

Figure 18 – Diagram of the test circuit for the verification of short-circuit making and breaking capacities of a two-pole contactor on single-phase a.c.



S	=	Supply
U_r1, U_r2, U_r3 U_r4, U_r5, U_r6	=	Voltage sensors
V	=	Voltage measuring device
A	=	Closing device
R_1	=	Adjustable resistor
N	=	Neutral of supply (or artificial neutral)
F	=	Fusible element (see 9.3.4.2.2 d))
X	=	Adjustable reactor
R_L	=	Fault current limiting resistor
D	=	Contactor under test (including connecting cables)
B	=	Temporary connection for calibration
I_1, I_2, I_3	=	Current sensors
T	=	Earth – One earthing point only (load side or supply side)
r	=	Shunt resistor (see 9.3.4.2.2 b))

NOTE 1 Adjustable loads X and R_1 may be located either on the high voltage side or on the low voltage side of the supply circuit, the closing device A being located on the low voltage side.

NOTE 2 U_r1, U_r2, U_r3 may, alternatively, be connected between phase and neutral.

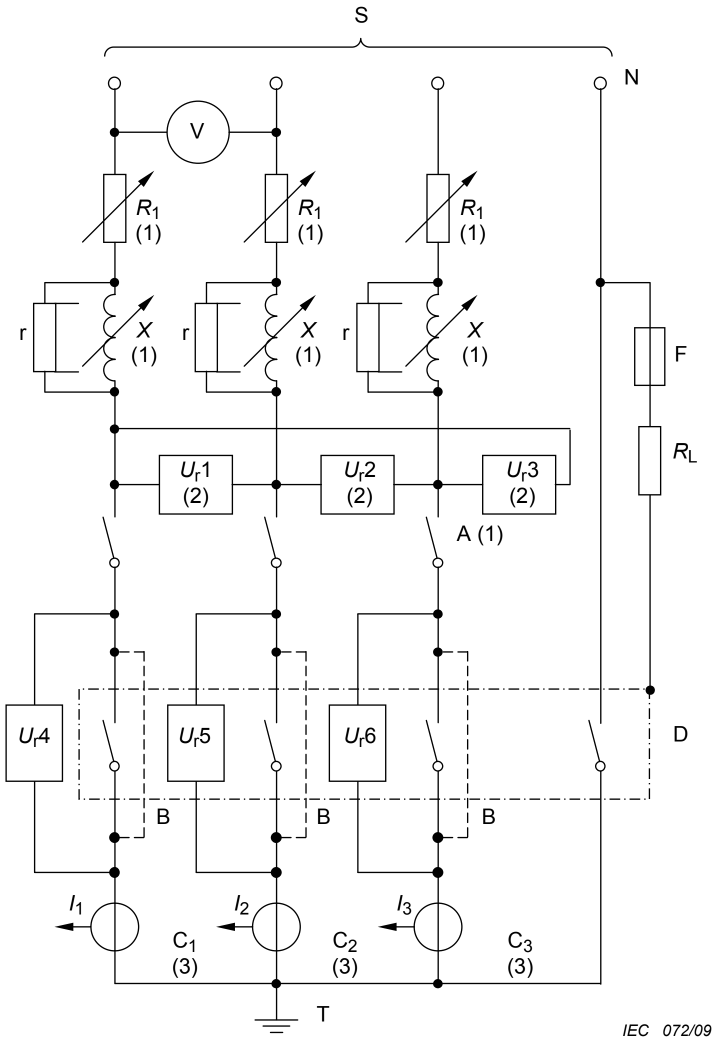
NOTE 3 In the case of equipment intended for use in phase-earthed systems or if this diagram is used for the test of the neutral and adjacent pole of a 4-pole equipment, F shall be connected to one phase of the supply.

NOTE 4 In the USA and Canada, F shall be connected:

– to one phase of the supply for equipment marked with a single value of U_e

– to the neutral for equipment marked with a twin voltage for U_e (see Note 1 to 6.2).

Figure 19 – Diagram of the test circuit for the verification of short-circuit making and breaking capacities of a three-pole contactor



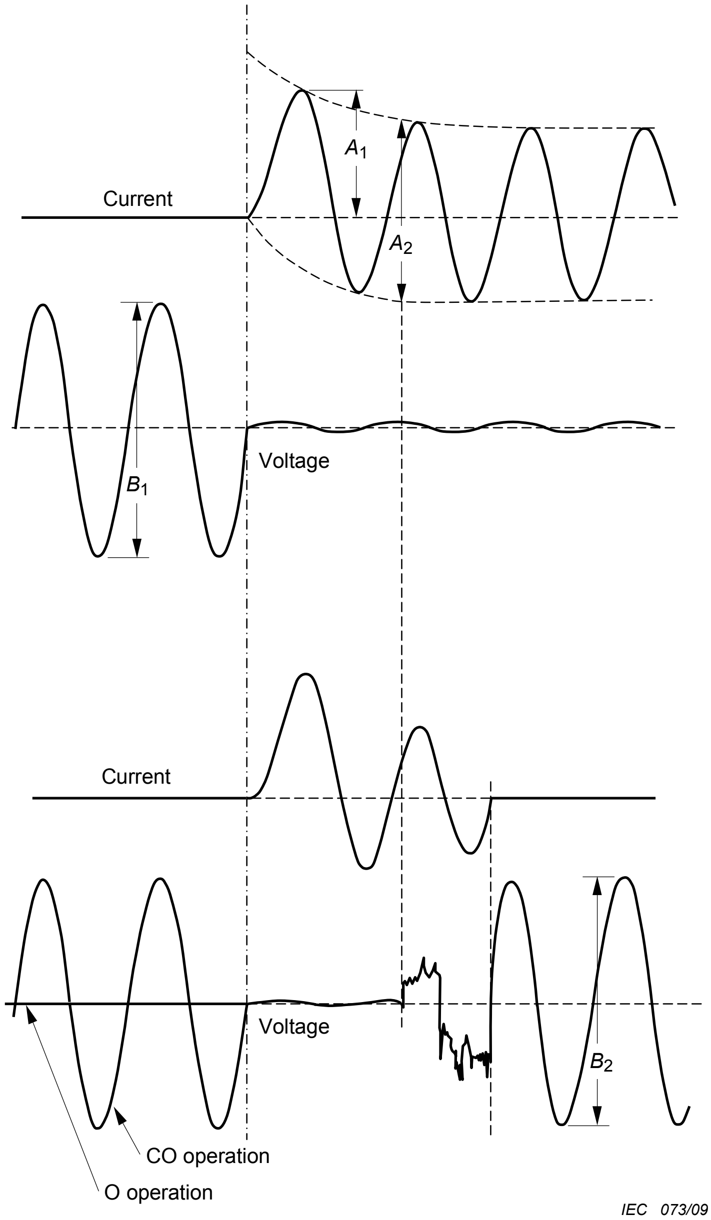
S	=	Supply
U_r1, U_r2, U_r3 U_r4, U_r5, U_r6	=	Voltage sensors
V	=	Voltage measuring device
R_1	=	Adjustable resistor
N	=	Neutral of supply
F	=	Fusible element (see 9.3.4.2.2 d))
X	=	Adjustable reactor
R_L	=	Fault current limiting resistor
A	=	Closing device
D	=	Contactor under test (including connecting cables)
B	=	Temporary connection for calibration
I_1, I_2, I_3	=	Current sensors
T	=	Earth – One earthing point only (load side or supply side)
r	=	Shunt resistor (see 9.3.4.2.2 b))

NOTE 1 Adjustable loads X and R_1 may be located either on the high voltage side or on the low voltage side of the supply circuit, the closing device A being located on the low voltage side.

NOTE 2 U_r1, U_r2, U_r3 may, alternatively, be connected between phase and neutral.

NOTE 3 If an additional test is required between the neutral pole and the adjacent pole, the connections C1 and C2 are omitted.

Figure 20 – Diagram of the test circuit for the verification of short-circuit making and breaking capacities of a four-pole contactor



a) = *Calibration of circuit*

A_1 = Prospective peak making current

$\frac{A_2}{2\sqrt{2}}$ = Prospective symmetrical breaking current (r.m.s. value)

$\frac{B_1}{2\sqrt{2}}$ = Applied voltage (r.m.s. value)

b) = *O or CO operation*

$\frac{B_2}{2\sqrt{2}}$ = Supply voltage (r.m.s. value)

Making capacity (peak value) = A_1*

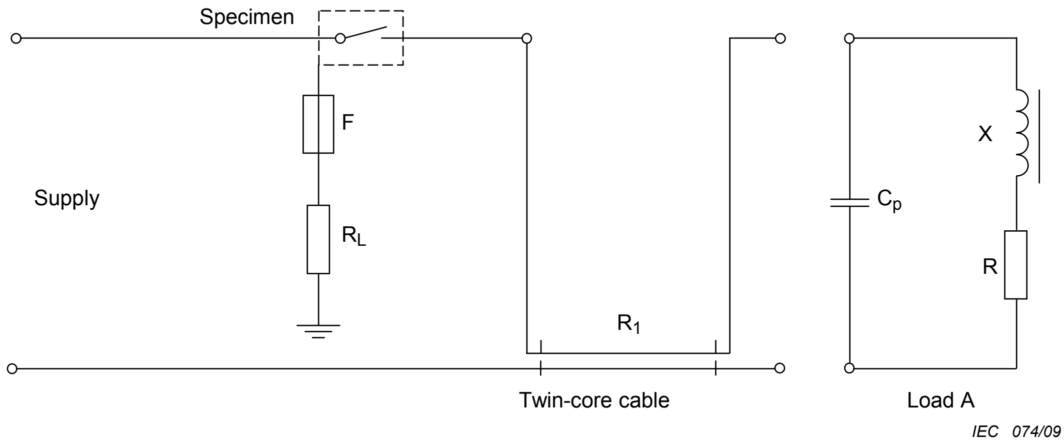
Breaking capacity (r.m.s. value) = $\frac{A_2{}^*}{2\sqrt{2}}$

NOTE 1 The amplitude of the voltage trace, after initiation of the test current, varies according to the relative positions of the closing device, the adjustable impedances, the voltage sensors and according to the test circuit diagram.

NOTE 2 It is assumed that the instant of making is the same for calibration and test.

* See 9.3.4.2.6 b).

Figure 21 – Example of short-circuit making and breaking test record in the case of a single-pole contactor on single-phase a.c.



Key

F	= Fuse
R_L , R_1 , R	= Resistors
X	= Inductor
C_p	= Capacitor

Figure 22 – Diagram of the test circuit for making and breaking verification for utilization category AC-7c

Annex A
(normative)

Terminal marking and distinctive number

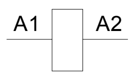
A.1 General

The purpose of identifying terminals of contactors is to provide information regarding the function of each terminal, or its location with respect to other terminals, or for other use.

A.2 Terminal marking of impedances (alphanumerical)

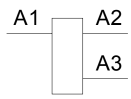
A.2.1 Coils

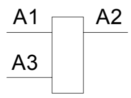
A.2.1.1 The two terminals of a coil for an electromagnetically operated drive shall be marked by A1 and A2.



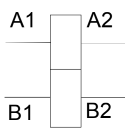
A.2.1.2 For a coil with tappings, the terminals of the tappings are marked in sequential order A3, A4, etc.

Examples:





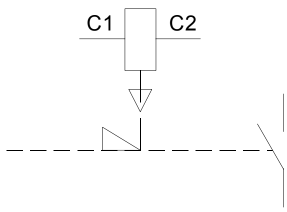
A.2.1.3 For a coil having two windings, the terminals of the first winding shall be marked A1, A2 and of the second winding B1, B2.



A.2.2 Electromagnetic releases

A.2.2.1 Shunt release

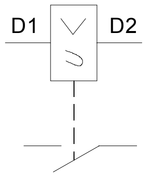
The two terminals of a shunt release shall be marked C1 and C2.



NOTE For a device with two shunt releases (for example with different ratings), the terminals of the second release should be marked preferably C3 and C4.

A.2.2.2 Under-voltage release

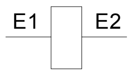
The two terminals of a coil intended to be used exclusively as an under-voltage release shall be marked D1 and D2.



NOTE For a device with two shunt releases (for example with different ratings), the terminals of the second release should be marked preferably D3 and D4.

A.2.3 Interlocking electromagnets

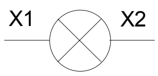
The two terminals of an interlocking electromagnet shall be marked E1 and E2.

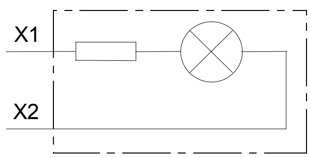


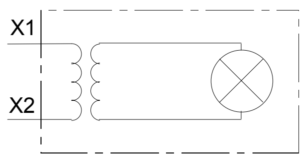
A.2.4 Indicating light devices

The two terminals of an indicating light device shall be marked X1 and X2.

Examples:







NOTE The term "indicating light devices" includes any incorporated resistor or transformer.

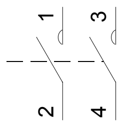
A.3 Terminal marking of contact elements for contactors with two positions (numerical)

A.3.1 Contact elements for main circuits (main contact elements)

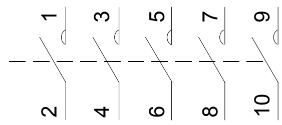
The terminals of main switching elements are identified by single figure numbers.

Each terminal marked by an odd number is associated with that terminal marked by the following even number.

Examples :



Two main contact elements



Five main contact elements

When a contactor has more than five main contact elements, alphanumerical marking shall be chosen, according to IEC 60445.

A.3.2 Contact elements for auxiliary circuit (auxiliary contact elements)

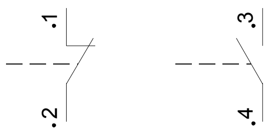
A.3.2.1 General

The terminals of auxiliary contact elements are identified by two-figure numbers:

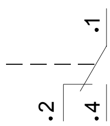
– the figure of the units is a function number;
– the figure of the tens is a sequence number.

A.3.2.2 Function number

A.3.2.2.1 Function numbers 1 and 2 are allocated to break-contact elements and functions 3 and 4 to make-contact elements.



The terminals of change-over contact elements are marked by the function numbers 1, 2 and 4.

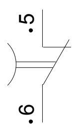


NOTE The definitions of break-contact element and make-contact element are given in IEC 60050-441.

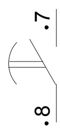
A.3.2.2.2 Auxiliary contact elements with special functions, such as time-delayed auxiliary contact elements, are identified by the function numbers 5 and 6, 7 and 8 for break-contact elements and make-contact elements respectively.

Examples:

Break-contact delayed on closing



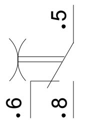
Make-contact delayed on closing



The terminals of change-over contact elements with special functions are marked by the function numbers 5, 6 and 8.

Example:

Change-over contact delayed in both directions

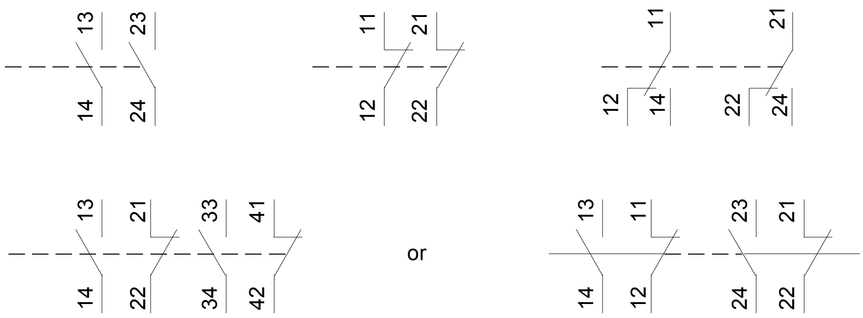


A.3.2.3 Sequence number

A.3.2.3.1 Terminals belonging to the same contact elements are marked with the same sequence numbers.

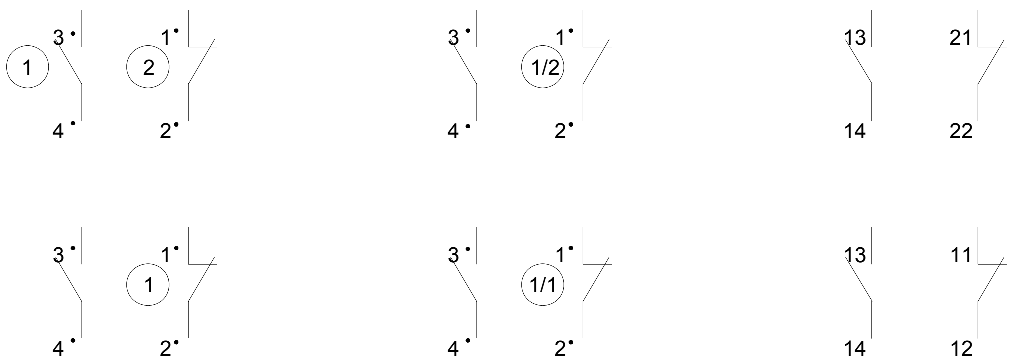
All contact elements having the same function shall have different sequence numbers.

Examples:



A.3.2.3.2 The sequence number may be omitted from the terminals only if additional information provided by the manufacturer or the user clearly gives such a number.

Examples:



Device   Device   Diagram

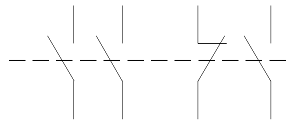
NOTE The dots shown in the examples of A.3.2 are merely used to show the relationship and do not need to be used in practice.

A.4 Distinctive number

A device with a fixed number of make-contact elements and break-contact elements may be allocated a two-figure distinctive number.

The first figure indicates the number of make-contact elements and the second figure the number of break-contact elements.

Distinctive number 31



Annex B
(normative)

Test sequences and number of samples

B.1 Test sequences

The tests are made according to Table B.1, where the tests in each sequence are carried out in the order indicated.

Table B.1 – Test sequences

Test sequences	Subclauses	Tests or inspections
A	9.3.3.3 9.3.3.2 9.3.3.5	Temperature-rise limits Operation and operating limits Rated making and breaking capacities [c]
B	9.3.3.4 9.3.3.6	Dielectric properties [a, c] Conventional operational performance
C	9.2.2.2 9.3.5 9.2.2.5	Resistance to humidity Ability to withstand overload currents Resistance to rusting
D	9.2.7 9.2.6 9.3.3.4	Durability of marking Resistance to impact Verification of clearances when necessary and verification of creepage distances
E	9.2.5 9.2.3 9.2.2.3 9.2.2.4 9.2.2.6	Mechanical properties of terminals Screws, nuts, current carrying parts Resistance to heat Resistance to abnormal heat and fire hazard Resistance to tracking [b]
F	9.2.2.1 9.2.4	Resistance to ageing Degrees of protection
G	9.3.4	Performance under short-circuit conditions

[a] Dielectric withstand test only, without measurement of clearances and creepage distances.

[b] In case where no tests on specimen of insulating materials are available.

[c] Test 9.3.3.5 in test sequence A and test 9.3.3.4 in test sequence B may be inverted at the manufacturer's option.

B.2 Number of samples

The number of samples to be submitted to the different test sequences are those indicated in the following Table B.2.

The samples required for a test sequence are submitted to all the tests of this test sequence and the requirements are met if all the tests are satisfied.

If only one of the samples does not satisfy a test in a given test sequence due to an assembly or manufacturing fault, which is not representative of the design, that test and any preceding ones which may have influenced the results of the test, shall be repeated on another full set of samples. Requirements are met if all the repeated tests are satisfied.

Table B.2 – Number of samples to be tested

Test sequences	Number of samples
A	3
B	3
C	1
D	1
E	1
F	1
G	4 [a]

[a] One sample may be used for each operation if necessary (see 9.3.4.3).

Annex C
(normative)

Description of a method for adjusting the load circuit

To adjust the load circuit to obtain the characteristics prescribed in 9.3.3.5.3 several methods may be applicable in practice. One of them is described below.

The principle is illustrated in Figure 16.

The oscillatory frequency f of the transient recovery voltage and the value of the factor γ are essentially determined by the natural frequency and the damping of the load circuit. Since these values are independent of the voltage and frequency applied to the circuit, the adjustment can be made by energizing the load circuit from an a.c. power supply, the voltage and frequency of which may be different from those of the supply source utilized for the test of the contactor. The circuit is interrupted at a current zero by a diode, and the oscillations of the recovery voltage are observed on the screen of a cathode-ray oscilloscope, the sweep of which is synchronized with the frequency of the power supply (see Figure C.1).

To permit reliable measurements to be made, the load circuit is energized by means of a high-frequency generator G giving a voltage suitable for the diode. The frequency of the generator is chosen equal to:

a) 2 kHz for test currents up to and including 1 000 A;
b) 4 kHz for test currents higher than 1 000 A.

Connected in series with the generator are:

– a dropping resistor having a resistance value R_a high with respect to the load circuit impedance ($R_a \geq 10\ Z$, where $Z = \sqrt{R^2 + (\omega L)^2}$ and where ω is $2\pi \times 2\ 000\ s^{-1}$ or $2\pi \times 4\ 000\ s^{-1}$ for cases a) and b) respectively;
– an instantaneously blocking switching diode B; switching diodes commonly used in computers such as diffused junction silicon switching diodes of not over 1 A forward rated current are suitable for this application.

Due to the value of frequency of the generator G, the load circuit is practically purely inductive and, at the instant of current zero, the applied voltage across the load circuit will be at its peak value. To ensure that the components of the load circuit are suitable, it must be checked on the screen that the curve of the transient voltage at its initiation (point A in Figure C.1) has a practically horizontal tangent.

The actual value of the factor γ is the ratio U_{11}/U_{12}; U_{11} is read on the screen, U_{12} is read between the ordinate of point A and the ordinate of the trace when the load circuit is no longer energized by the generator (see Figure C.1).

When observing the transient voltage in the load circuit with no resistor R_p or capacitor C_p in parallel, one reads on the screen the natural oscillatory frequency of the load circuit. Care should be taken that the capacitance of the oscilloscope or of its connecting leads does not influence the resonant frequency of the load circuit.

If that natural frequency exceeds the upper limit of the required value f, the suitable values of frequency and factor γ can be obtained by connecting in parallel capacitors C_p and resistors R_p of appropriate values. The resistors R_p shall be practically non-inductive.

It is recommended that, as a first step, each of the three phases of the load circuit be adjusted separately. The adjustment is then completed by successively connecting, in each possible combination, the high-frequency generator to one phase in series with the other two in parallel as shown in Figure 16; the adjustment is refined if necessary so that the specified values of f and γ are obtained in each combination.

NOTE 1 A higher value of frequency obtained from the generator G facilitates the observation on the screen and improves the resolution.

NOTE 2 Other methods of determining frequency and factor γ (such as the impression of a square-wave current on the load circuit) may also be used.

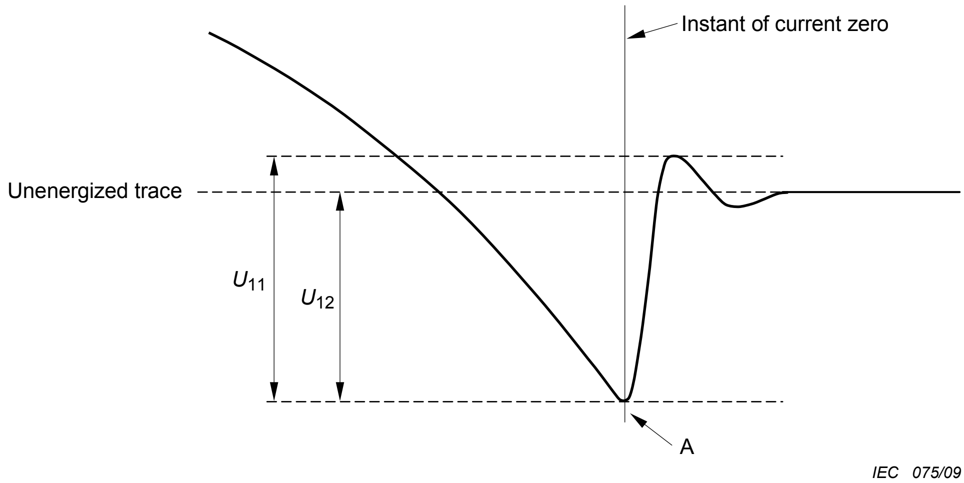


Figure C.1 – Determination of the actual value of the factor γ

Annex D
(normative)

Determination of short-circuit power-factor

D.1 General

There is no method by which the short-circuit power-factor can be determined with precision, but for the purpose of this standard, the determination of the power-factor of the test circuit may be made by one of the following methods.

NOTE Other methods for determining the short-circuit power-factor are under consideration.

D.2 Method I – Determination from d.c. component

The angle φ may be determined from the curve of the d.c. component of the asymmetrical current wave between the instant of the short-circuit and the instant of contact separation as follows:

1. To determine the time-constant L/R from the formula for the d.c. component.

   The formula for the d.c. component is:

   $$i_d = I_{do}\, e^{-Rt/L}$$

   where

   i_d is the value of the d.c. component at the instant t ;

   I_{do} is the value of the d.c. component at the instant taken as time origin ;

   L/R is the time-constant of the circuit, in seconds ;

   t is the time, in seconds, taken from the initial instant ;

   e is the base of Napierian logarithms.

   The time-constant L/R can be determined by:

   a) measuring the value of I_{do} at the instant of short-circuit and the value of i_d at another instant t before contact separation,

   b) determining the value of $e^{-Rt/L}$ by dividing i_d by I_{do},

   c) determining the value of $-\chi$ corresponding to the ratio i_d/I_{do}, from a table of values of e^{-x}.

   The value χ represents Rt/L, from which R/L is obtained.

2. To determine the angle φ from: $\varphi = \text{arc tg}\,(\omega L/R)$

   where ω is $2\,\pi$ times the actual frequency.

This method should not be used when the currents are measured by current transformers, except if suitable precautions are taken to eliminate errors due to:

– the time-constant of the transformer and its burden in relation to that of the primary circuit;

– magnetic saturation which can result from the transient flux conditions combined with possible remanence.

D.3 Method II – Determination with pilot generator

When a pilot generator is used on the same shaft as the test generator, the voltage of the pilot generator on the oscillogram may be compared in phase first with the voltage of the test generator and then with the current of the test generator.

The difference between the phase angles between pilot generator voltage and main generator voltage on the one hand, and pilot generator voltage and test generator current on the other hand, gives the phase angle between the voltage and current of the test generator, from which the power-factor can be determined.

Annex E
(normative)

Measurement of creepage distances and clearances

E.1 Basic principles

The widths *X* of grooves specified in Figures E.2 to E.12 basically apply to all examples as a function of pollution degree as follows:

Pollution degrees	**Minimum values of width *X* of grooves** mm
1	0,25
2	1,0
3	1,5
4	2,5

If the associated clearance is less than 3 mm, the minimum groove width may be reduced to one-third of this clearance.

The methods of measuring creepage distances and clearances are indicated in the following Figures E.2 to E.12. These examples do not differentiate between gaps and grooves or between types of insulation.

Furthermore:

– any corner is assumed to be bridged with an insulating link of *X* mm width moved into the most unfavourable position (see Figure E.4);

– when the distance across the top of a groove is *X* mm or more, a creepage distance is measured along the contours of the groove (see Figure E.3);

– creepage distances and clearances measured between parts moving in relation to each other are measured when these parts are in their most unfavourable positions.

E.2 Use of ribs

Because of their influence on contamination and their better drying-out effect, ribs decrease considerably the formation of leakage current. Creepage distances can therefore be reduced to 0,8 times the required value, provided the minimum height of the ribs is 2 mm.

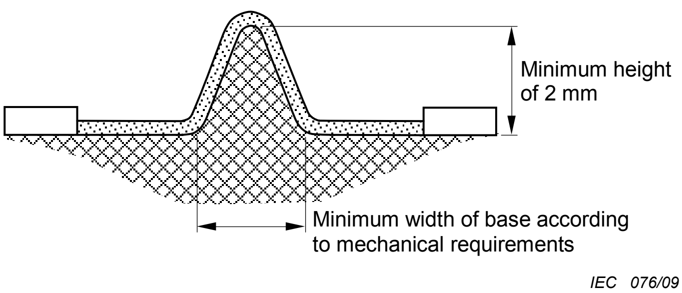
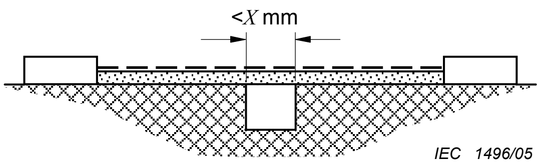


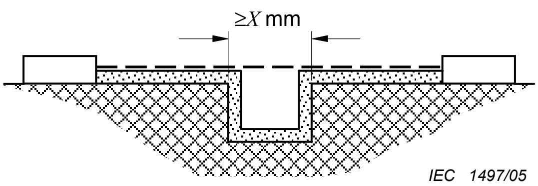
Figure E.1 – Measurement of ribs



Condition: This creepage distance path includes a parallel- or converging-sided groove of any depth with a width less than X mm.

Rule: Creepage distance and clearance are measured directly across the groove as shown.

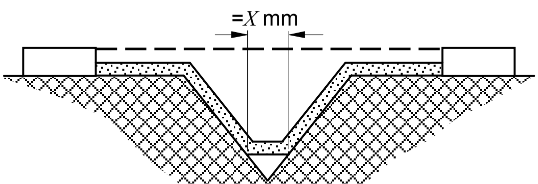
Figure E.2 – Creepage distance example 1



Condition: This creepage distance path includes a parallel-sided groove of any depth and a width equal to or more than X mm.

Rule: Clearance is the "line-of-sight" distance. Creepage distance path follows the contour of the groove.

Figure E.3 – Creepage distance example 2



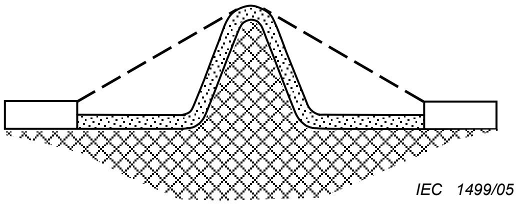
Condition: This creepage distance path includes a V-shaped groove with a width greater than X mm.

Rule: Clearance is the "line-of-sight" distance. Creepage distance path follows the contour of the groove but "short-circuits" the bottom of the groove by X mm link.

Figure E.4 – Creepage distance example 3

– – – – – – Clearance

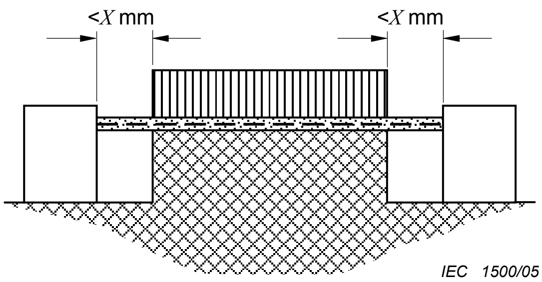
Creepage distance



Condition: This creepage distance path includes a rib.

Rule: Clearance is the shortest air path over the top of the rib. Creepage path follows the contour of the rib.

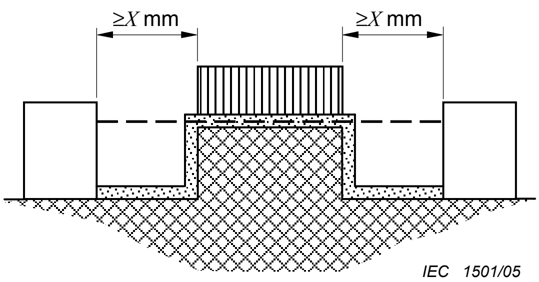
Figure E.5 – Creepage distance example 4



Condition: This creepage distance path includes an uncemented joint with grooves less than X mm wide on each side.

Rule: Creepage distance and clearance path is the "line-of-sight" distance shown.

Figure E.6 – Creepage distance example 5



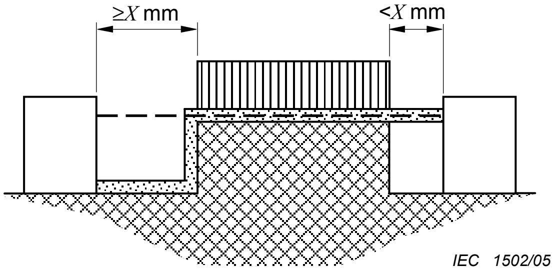
Condition: This creepage distance path includes an uncemented joint with grooves equal to or more than X mm wide on each side.

Rule: Clearance is the "line-of-sight" distance. Creepage distance path follows the contour of the grooves.

Figure E.7 – Creepage distance example 6

– – – – – – Clearance

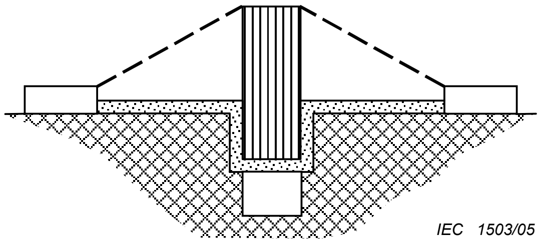
[dotted] Creepage distance



Condition: This creepage distance path includes an uncemented joint with a groove on one side less than X mm wide and the groove on the other side equal to or more than X mm wide.

Rule: Clearance and creepage distance paths are as shown.

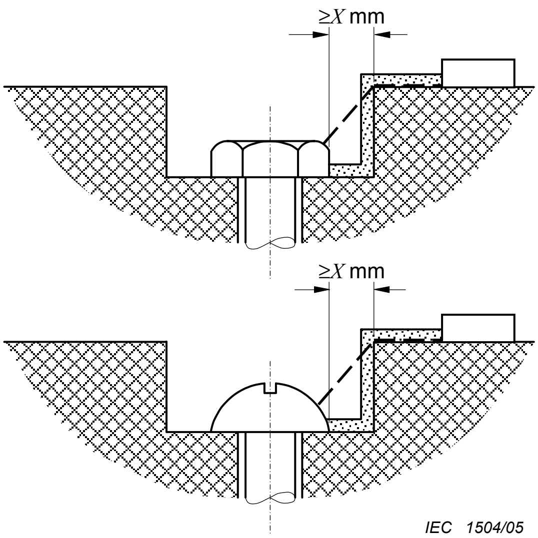
Figure E.8 – Creepage distance example 7



Condition: Creepage distance through uncemented joint is less than creepage distance over barrier.

Rule: Clearance is the shortest direct air path over the top of the barrier.

Figure E.9 – Creepage distance example 8



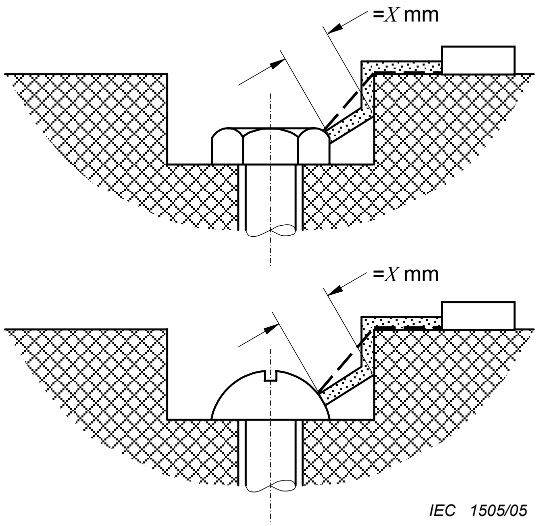
Condition: Gap between head of screw and wall of recess wide enough to be taken into account.

Rule: Clearance and creepage distance paths are as shown.

Figure E.10 – Creepage distance example 9

– – – – – – Clearance

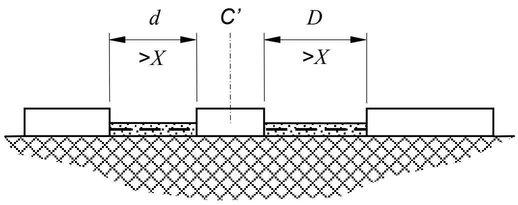
Creepage distance



Condition: Gap between head of screw and wall of recess too narrow to be taken into account.

Rule: Measurement of creepage distance is from screw to wall when the distance is equal to X mm.

Figure E.11 – Creepage distance example 10



C' Floating part

Clearance is the distance = *d* + *D*

Creepage distance is also = *d* + *D*

Figure E.12 – Creepage distance example 11

– – – – – – Clearance

Creepage distance

Annex F
(normative)

Correlation between the nominal voltage of the supply system and the rated impulse withstand voltage of a contactor

This annex is intended to give the necessary information concerning the choice of a contactor for use in a circuit within an electrical system or part thereof.

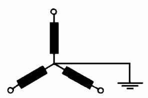
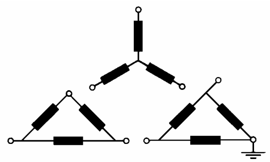
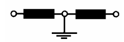
Table F.1 provides examples of the correlation between supply system voltages and the corresponding rated impulse withstand voltage of a contactor.

The values of rated impulse withstand voltage given in Table F.1 are based on the performance characteristics of surge arresters.

It should also be recognized that control of over-voltages with respect to the values in Table F.1 can also be achieved by conditions in the supply system such as the existence of a suitable impedance or cable feed.

In such cases where the control of over-voltages is achieved by means other than surge arresters, guidance for the correlation between the nominal supply system voltage and the equipment rated impulse withstand voltage is given in IEC 60364-4-44.

Table F.1 – Correspondence between the nominal voltage of the supply system and the contactor rated impulse withstand voltage, in case of over-voltage protection by surge-arresters according to IEC 60099-1

Maximum value of rated operational voltage to earth	Nominal voltage of the supply system (≤ rated insulation voltage of the equipment)				Preferred values of rated impulse withstand voltage (1,2/50 µs) at 2 000 m kV			
					Over-voltage category			
					IV	III	II	I
a.c. r.m.s. or d.c. V	 a.c. r.m.s. V	 a.c. r.m.s. V	 a.c. r.m.s. or d.c. V	 a.c. r.m.s. or d.c. V	Origin of installation (service entrance) level	Distribution circuit level	Load (appliance, equipment) level	Specially protected level
50	–	–	12,5, 24, 25 30, 42, 48	60-30	1,5	0,8	0,5	0,33
100	66/115	66	60	–	2,5	1,5	0,8	0,5
150	120/208 127/220	115, 120 127	110, 120	220-110, 240-120	4	2,5	1,5	0,8
300	220/380, 230/400 240/415, 260/440 277/480	220, 230 240, 260 277	220	440-220	6	4	2,5	1,5

Annex G
(normative)

Hot wire ignition test

G.1 Five samples of each material shall be tested. The samples shall be 150 mm long by 13 mm wide and of uniform thickness representing the thinnest section of the part.

Edges shall be free from burrs, fins, etc.

G.2 A 250 mm ± 5 mm length of nichrome wire (80 % nickel, 20 % chromium, iron free) approximately 0,5 mm diameter and having a cold resistance of approximately 5,28 Ω/m shall be used. The wire shall be connected in a straight length to a variable source of power which is adjusted to cause a power dissipation of 0,26 W/mm in the wire for a period of 8 s to 12 s. After cooling, the wire shall be wrapped around a sample to form five complete turns spaced 6 mm apart.

G.3 The wrapped sample shall be supported in a horizontal position and the ends of the wire connected to the variable power source which is again adjusted to dissipate 0,26 W/mm in the wire (see Figure G.1).

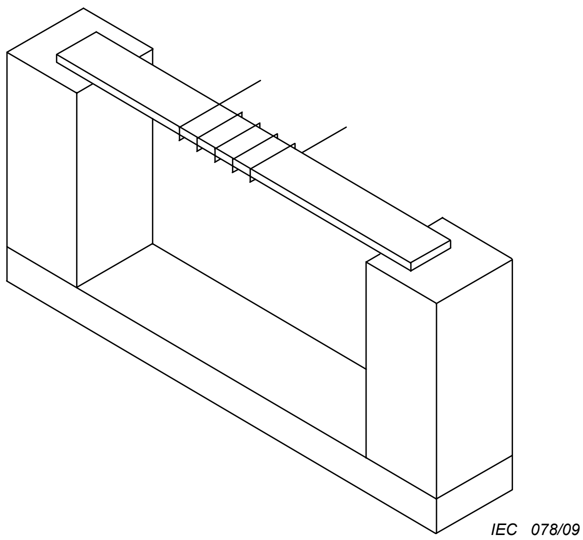


Figure G.1 – Test fixture for hot wire ignition test

G.4 Start the test by energizing the circuit so that a current is passed through the heater wire yielding a linear power density of 0,26 W/mm.

G.5 Continue heating until the test specimen ignites. When ignition occurs, shut off power and record time to ignite. Discontinue the test if ignition does not occur within 120 s.

For specimens that melt through the wire without ignition, discontinue the test when the specimen is no longer in intimate contact with all five turns of the heater wire.

G.6 The test shall be repeated on the remaining samples.

G.7 The hot wire ignition time of the material shall be recorded as the average ignition time of the specimens tested.

Annex H
(normative)

Degrees of protection of enclosed contactor

H.0 Guide to the use of Annex H

Where an IP code is stated by the manufacturer for a contactor with integral enclosure or for an enclosed contactor, the requirements of IEC 60529:1989 apply with the following.

NOTE Figure H.1 gives further information to facilitate the understanding of the IP code covered by IEC 60529.

Clauses and subclauses of IEC 60529 applicable to a contactor with integral enclosure and to an enclosed contactor are explicitly detailed in this annex.

Clause and subclause numbers of this annex are sometimes discontinuous because they correspond to those of IEC 60529.

H.1 Scope and object

This annex applies to the degrees of protection of a contactor with integral enclosure and of an enclosed contactor at rated voltages not exceeding 440 V a.c. hereafter referred to as “device”.

Clause 1 of IEC 60529 applies with the additional requirements of this annex.

H.3 Terms and definitions

Clause 3 of IEC 60529 applies except that "enclosure" (3.1) is replaced by the following, Note 1 and Note 2 remaining as they are.

"A part providing a specified degree of protection of device against certain external influences and a specified degree of protection against approach to or contact with live parts and moving parts."

[IEV 441-13-01, modified]

NOTE This definition given in 3.1.16 of this standard is similar to IEV 441-13-01 which applies to assemblies.

H.4 Designation

Clause 4 of IEC 60529 applies except for letters H, M and S.

H.5 Degrees of protection against access to hazardous parts and against ingress of solid foreign objects indicated by the first characteristic numeral

Clause 5 of IEC 60529 applies.

H.6 Degrees of protection against ingress of water indicated by the second characteristic numeral

Clause 6 of IEC 60529 applies.

H.7 Degrees of protection against access to hazardous parts indicated by the additional letter

Clause 7 of IEC 60529 applies.

H.8 Supplementary letters

Clause 8 of IEC 60529 applies except for letters H, M and S.

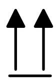
H.9 Examples of designations with IP Code

Clause 9 of IEC 60529 applies.

H.10 Marking

Clause 10 of IEC 60529 applies with the following addition.

If the IP Code is designated for one mounting position only, it shall be indicated by the symbol of ISO 7000-0623 placed next to the IP Code specifying this position of the device, e.g. vertical:



H.11 General requirements for tests

H.11.1 Subclause 11.1 of IEC 60529 applies.

H.11.2 Subclause 11.2 of IEC 60529 applies with the following additions.

All tests are made in the unenergized state.

Certain devices (e.g. exposed faces of push-buttons) can be verified by inspection.

The temperature of the test sample shall not deviate from the actual ambient temperature by more than 5 K.

Where device is mounted in an empty enclosure which already has an IP Code (see 11.5 of IEC 60529) the following requirements apply.

a) For IP1X to IP4X and additional letters A to D.

   This shall be verified by inspection and compliance with the enclosure manufacturer's instructions.

b) For IP6X dust test.

   This shall be verified by inspection and compliance with the enclosure manufacturer's instructions.

c) For IP5X dust test and IPX1 to IPX8 water tests.

   Testing of the enclosed device is only required where the ingress of dust or water may impair the operation of the device.

NOTE IP5X dust and IPX1 to IPX8 water tests allow the ingress of a certain amount of dust and water provided that there are no harmful effects. Every internal device configuration should, therefore, be separately considered.

H.11.3 Subclause 11.3 of IEC 60529 applies with the following addition :

Drain and ventilating holes are treated as normal openings.

H.11.4 Subclause 11.4 of IEC 60529 applies.

H.11.5 Where an empty enclosure is used as a component of an enclosed device, 11.5 of IEC 60529 applies.

H.12 Tests for protection against access to hazardous parts indicated by the first characteristic numeral

Clause 12 of IEC 60529 applies except for 12.3.2.

H.13 Tests for protection against ingress of solid foreign objects indicated by the first characteristic numeral

Clause 13 of IEC 60529 applies except for:

13.4 Dust test for first characteristic numerals 5 and 6

The following text to be added:

Enclosed device having a degree of protection IP5X shall be tested according to category 2 of 13.4 of IEC 60529.

Enclosed device having a degree of protection IP6X shall be tested according to category 1 of 13.4 of IEC 60529.

NOTE For enclosed device according to this standard, a degree of protection IP5X is generally deemed satisfactory.

13.5.2 Acceptance conditions for first characteristic numeral 5

The following text to be added:

Where dust deposits could raise doubts as to the correct functioning and safety of device, a preconditioning and a dielectric test shall be conducted as follows:

The preconditioning, after the dust test, shall be verified by test Cab: damp heat, steady state, according to IEC 60068-2-78, under the following test conditions.

The device shall be prepared so that the dust deposits are subject to the test by leaving open the lid and/or removing parts, where possible without the aid of tool.

Before being placed in the test chamber the device shall be stored at room temperature for at least 4 h before the test.

The test duration shall be 24 consecutive hours.

After this period, the device is to be removed from the test chamber within 15 min and submitted to a power-frequency dielectric test for 1 min, the value being 2 U_e max with a minimum of 1 000 V. The application of the test voltage and the acceptance criteria shall be as specified in 9.3.3.4.1, item b) 3) and item b) 4).

H.14 Tests for protection against water indicated by second characteristic numeral

H.14.1 Subclause 14.1 of IEC 60529 applies.

H.14.2 Subclause 14.2 of IEC 60529 applies.

H.14.3 Subclause 14.3 of IEC 60529 applies with the following addition:

The device is then submitted to a power-frequency dielectric test for 1 min, the value being 2 U_e max. with a minimum of 1 000 V. The application of the test voltage and the acceptance criteria shall be as specified in 9.3.3.4.1, item b) 3) and item b) 4).

H.15 Tests for protection against access to hazardous parts indicated by additional letter

Clause 15 of IEC 60529 applies.

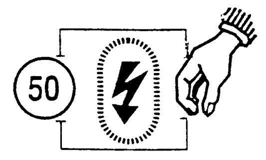
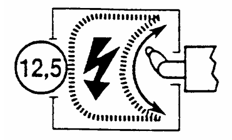
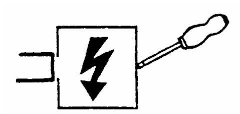
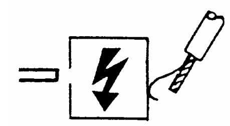
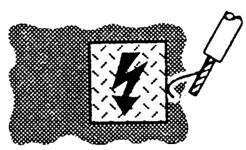
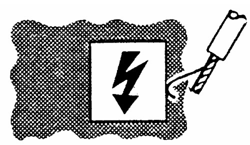
H.1a – FIRST NUMERAL			
Protection against ingress of solid objects			**Protection of persons against access to hazardous parts with:**
IP	**Requirements**	**Examples**	
0	No protection		Non-protected
1	Full penetration of 50 mm diameter sphere not allowed. Contact with hazardous parts not permitted		Back of hand
2	Full penetration of 12,5 mm diameter sphere not allowed. The jointed test finger shall have adequate clearance from hazardous parts		Finger
3	The access probe of 2,5 mm diameter shall not penetrate		Tool
4	The access probe of 1,0 mm diameter shall not penetrate		Wire
5	Limited ingress of dust permitted (no harmful deposit)		Wire
6	Totally protected against ingress of dust		Wire

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Figure H.1 – IP Codes

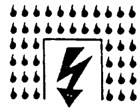
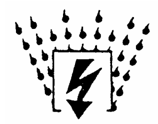
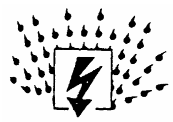
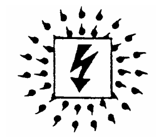
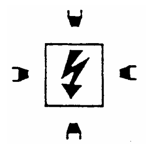
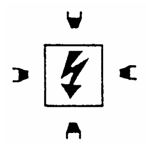
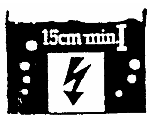
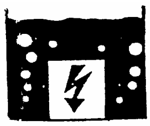
H.1b – SECOND NUMERAL			
Protection against harmful ingress of water			Protection from water
IP	Prescriptions	Examples	
0	No protection		Non-protected
1	Protected against vertically falling drops of water. Limited ingress permitted		Vertically dripping
2	Protected against vertically falling drops of water with enclosure tilted 15° from the vertical. Limited ingress permitted		Dripping up to 15° from the vertical
3	Protected against sprays to 60° from the vertical. Limited ingress permitted		Limited spraying
4	Protected against water splashed from all directions. Limited ingress permitted		Splashing from all directions
5	Protected against jets of water. Limited ingress permitted		Hosing jets from all directions
6	Protected against strong jets of water. Limited ingress permitted		Strong hosing jets from all directions
7	Protected against the effects of immersion between 15 cm and 1 m		Temporary immersion
8	Protected against long periods of immersion under pressure		Continuous immersion

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Figure H.1 *(continued)*

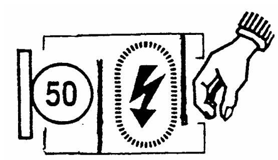
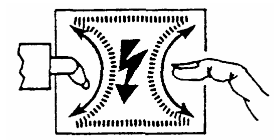
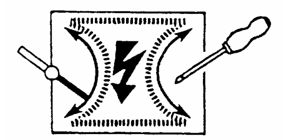
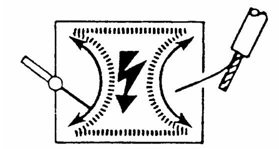
H.1c – ADDITIONAL LETTER (optional)			
IP	**Requirements**	**Examples**	**Protection of persons against access to hazardous parts with :**
A For use with first numeral 0	Penetration of 50 mm diameter sphere up to barrier must not contact hazardous parts		Back of hand
B For use with first numerals 0 and 1	Test finger penetration to a maximum of 80 mm must not contact hazardous parts		Finger
C For use with first numerals 1 and 2	Wire of 2,5 mm diameter × 100 mm long must not contact hazardous parts when spherical stop face is partially entered		Tool
D For use with first numerals 2 and 3	Wire of 1,0 mm diameter × 100 mm long must not contact hazardous parts when spherical stop face is partially entered		Wire

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Figure H.1 *(continued)*

Annex I
(normative)

Requirements and tests for equipment with protective separation

I.1 General

This annex applies to a device one or more circuits of which being able to be used in SELV (PELV) circuit (the device by itself may not be Class III, see 7.4 of IEC 61140:2001).

The purpose of this annex is to harmonize as far as practicable all rules and requirements applicable to low voltage switchgear and controlgear having a protective separation between parts intended to be used in SELV (PELV) circuits and others, in order to obtain uniformity of requirements and tests and to avoid the need for testing to different standards.

I.2 Terms and definitions

I.2.1
functional insulation
insulation between conductive parts which is necessary only for the proper functioning of the equipment

I.2.2
basic insulation
insulation of hazardous live parts which provides basic protection against electric shock

NOTE The term basic insulation does not apply to insulation used exclusively for functional purposes. (See I.2.1)

I.2.3
supplementary insulation
independent insulation applied in addition to basic insulation in order to provide protection against electric shock in the event of a failure of basic insulation

I.2.4
double insulation
insulation comprising both basic insulation and supplementary insulation

I.2.5
reinforced insulation
insulation of hazardous live parts which provides a degree of protection against electric shock equivalent to double insulation

NOTE Reinforced insulation may comprise several layers which cannot be tested singly as basic or supplementary insulation.

I.2.6
(electrically) protective separation
separation of one electric circuit from another by means of:

– double insulation, or
– basic insulation and electrically protective screening, or
– reinforced insulation

[IEV 195-06-19]

I.2.7
SELV circuit
electrical circuit in which the voltage cannot exceed ELV:

– under normal conditions, and
– under single-fault conditions, including earth faults in other circuits

NOTE Definition adapted from the definition of SELV system given in 3.26.1 of IEC 61140:2001.

I.2.8
PELV circuit
electrical circuit in which the voltage cannot exceed ELV:

– under normal conditions, and
– under single-fault conditions, except earth faults in other circuits

NOTE Definition adapted from the definition of PELV system given in 3.26.2 of IEC 61140:2001.

I.2.9
limitation of steady-state touch current and charge
protection against electric shock by circuit or equipment design such that under normal and fault conditions the steady-state touch current and charge are limited to non-hazardous levels

I.2.10
protective impedance device
component or assembly of components the impedance and construction of which are such as to ensure that steady-state touch current and charge are limited to non-hazardous levels

I.3 Requirements

I.3.1 General

The only method considered in this standard to achieve the protective separation is based on double (or reinforced) insulation between SELV (PELV) circuit(s) and other circuits. If any component is connected between the separated circuits, that component shall comply with the requirements for protective impedance devices according to 5.3.4 of IEC 61140:2001 (see Figure I.1).

The effects of electrical arcs normally produced in the breaking chambers of switchgears and controlgears on insulation are deemed to be taken into account in the dimensioning of creepage distances and no specific verification is required.

Partial discharge effects are not taken into consideration.

I.3.2 Dielectric requirements

I.3.2.1 Creepages

It shall be verified that the creepage distances between SELV (PELV) circuit and other circuits are equal or higher than twice those given for basic insulation in Table 18 and corresponding to the voltage of the circuit having the highest rated voltage value.

NOTE This requirement follows the principles given in IEC 60664-1.

The creepage distances shall be verified in accordance with I.4.2.1.

I.3.2.2 Clearances

The clearances between SELV (PELV) circuit and other circuits of the device shall be dimensioned to withstand the rated impulse voltage as determined in accordance with Annex F relevant to the basic insulation for the specific utilisation class but one step higher in the series value (or a value equal to 160 % of the voltage value required for the basic insulation) following the principles given in 5.1.6 of IEC 60664-1:2007. The test conditions are given in I.4.2.2.

I.3.3 Construction requirements

Construction measures should be taken regarding:

– materials employed regarding aging;
– thermal stresses or mechanical risks of failure which will impair insulation between circuits;
– risks of electrical contact between different circuits in case of accidental disconnection of wiring.

Subclause I.4.3 gives examples of constructional risks which have to be taken into consideration.

I.4 Tests

I.4.1 General

These tests are normally conducted as type tests. Where the constructional design cannot ensure without doubt that the insulation intended for protective separation cannot be impaired by the effects of product conditions, the manufacturer may also conduct all or parts of these tests as routine tests.

Tests verification shall be made between the SELV (PELV) circuit and each other circuits, such as main circuit, control and auxiliary circuits.

Tests shall be done in all operating conditions of the device: open, close, trip positions.

I.4.2 Dielectric tests

I.4.2.1 Creepages verification

Conditions of measuring are those given in 9.3.3.4.1 and Annex E.

I.4.2.2 Clearances verification

I.4.2.2.1 Condition of the device for test

Tests shall be made on devices mounted as for service, including internal wiring and in a clean and dry condition.

I.4.2.2.2 Application of the test voltage

For each circuit of the device under test, external terminals shall be connected together.

I.4.2.2.3 Impulse test voltage

It shall be an impulse test voltage having a 1,2/50 µs wave form as described in 9.3.3.4.1, the value of which being chosen as defined in I.3.2.2.

I.4.2.2.4 Test

Clearances are verified by application of the test voltage of I.4.2.2.3. The test shall be conducted for a minimum of five impulses of each polarity with an interval of at least 1 s between pulses in accordance with in 9.3.3.4.1.

Application of test voltage may be avoided where clearances are equal or higher than those given in Table 17 for the determined test voltage value.

I.4.2.2.5 Results to be obtained

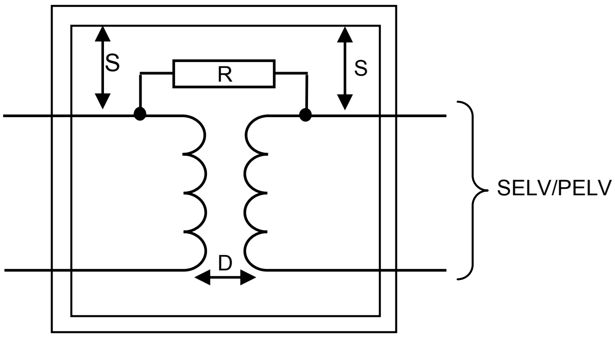
When the voltage is applied, the test is considered to have been passed if there is no puncture or flashover.

I.4.3 Examples of constructional measures

Measures should be taken that a single mechanical fault – e.g. a bent solder pin, a detached soldering point or a broken winding (coil), a loosened and fallen screw – should not have the result of impairing the insulation to such a degree that it no longer fulfils the requirements of the basic insulation; the design, however, should not consider that two or more of these events will appear simultaneously.

Examples of constructional measures:

– sufficient mechanical stability;
– mechanical barriers;
– employment of captive screws;
– impregnation or casting of components;
– inserting pins into an insulating sleeve;
– to avoid sharp-edges in the vicinity of conductors.



Key

D double (or reinforced) insulation between circuits (including SELV/PELV circuit)

R component complying with protective impedance devices requirements

S basic insulation

Figure I.1 – Example of application with component connected between separated circuits

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